Popular Astronomy.

Vol. XIX, No. 5. MAY, 1911. Whole No., 185.

THE COMPUTATION OF THE TIMES OF RISING AND SETTING OF THE MOON.

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The times of moonrise and moonset are given annually in the popular almanacs, for which they are computed with respect to certain latitudes and meridians so selected that the times computed for each may be approximately right throughout the corresponding section of the country. Occasionally, however, the observatory astronomer is called upon to give the time of rising or setting of the Moon for a particular date and place; and the astronomical photographer, the explorer or military commander is liable to have occasion to determine with some accuracy when moonlight will be present or when it will be absent. A glance at one of the better popular almanacs, or a brief inspection of certain pages of an astronomical ephemeris, suffices in many cases; but sometimes it is desirable to obtain quickly and with confidence the nearest minute for the rising or setting of the Moon for a particular place.

A statement of the solution of this problem is given in several text-books of astronomy; but, so far as I know, in none of them are presented both a clear statement of the steps of the computation and a full solution of several examples involving a variety of data. Such examples furnish a model and control and are convenient to the computer to have at hand.

My special purpose was to present a restatement of an ingenious and accurate solution which seems not to have received the attention it deserves, and for which we are indebted to Professor Edgar Frisby, U. S. N. (Laboratory Manual of Astronomy, by Mary E. Byrd, A. B., Appendix C, 1899). This method is of special value at fixed observatories, where it is customary to have sets of tables at hand to facilitate various computations. But at the close of this article will be found a statement of the ordinary method also and several examples illustrating both methods.

Professor Frisby employs a general formula from the spherical triangle between the zenith, the pole, and a given celestial object as follows:—

$$\cos z = \sin \delta \sin \phi + \cos \delta \cos \phi \cos t,$$

where the symbols have their conventional significance. From this we have

$$\cos t = \tan \delta \tan \phi \left(\frac{\cos z}{\sin \delta \sin \phi} - 1 \right), \qquad (1)$$

the general equation for any celestial body.

For the Moon it is customary to regard the time of rising or setting as the moment when the center of the disk is on the horizon. Consequently we have the apparent zenith distance increased by the horizontal refraction r and diminished by the parallax π; or

$$z = 90^\circ + (r - \pi),$$

and

$$\cos t = \tan \delta \tan \phi \left(\frac{\sin (\pi - r)}{\sin \delta \sin \phi} - 1 \right), \qquad (2)$$

the general equation for the Moon.

Professor Frisby proposes to compute the values of t for two special values of the parallax and interpolate between the two results in order to obtain the value of t corresponding to the actual value of the parallax. The first of these values is so chosen as to utilize the tables that may have been computed already at a given station to obtain the hour-angles of the Sun at rising or setting. For the Sun it is customary to regard the time of rising or setting as the moment when the upper limb is on the horizon. Consequently we have

$$z = 90^\circ + (r + s),$$

where s is the semidiameter of the Sun's disk.

Substituting in (1) we have

$$\cos t = -\tan \delta \tan \phi \left(\frac{\sin (r + s)}{\sin \delta \sin \phi} + 1 \right), \qquad (3)$$

the general equation for the Sun.

Now, if in this equation we substitute $180^\circ - t$ for t, $\pi - r$ for $r + s$, and change the sign of δ, we have

$$\cos(180^\circ - t) = \tan\delta \tan\phi \left(\frac{\sin(\pi - r)}{\sin\delta \sin\phi} - 1 \right).$$

The second member of this equation is identidal with that of (2). Consequently, if t be computed for the Sun by (3) with the same declination as that of the Moon, but with the opposite sign, and then t be subtracted from 180°, or 12^h, the result will be the same as if t were computed directly for the Moon by (2), with the parallax $\pi = 2r + s$. Or if we have tables of semi-diurnal arcs already computed for the Sun, the tabular numbers will hold also for the Moon, with parallax $\pi = 2r + s$, if they be treated in accordance with the precept just given. For instance, if the tables were computed with the values 36′ and 16′ adopted for the refraction and semi-diameter respectively, then we have for the corresponding parallax of the Moon 88′; and sin $(\pi - r)$ in (2) becomes sin 52′, or log sin $(\pi - r)$ is 8.17971, as given later in the scheme of computation.

Second, if we put $\pi - r = 0$ in (2) the equation becomes simply

$$\cos t = -\tan\delta \tan\phi\,, \qquad (4)$$

which is the equation for the Moon when we have $\pi = r$, that is, $\pi = 36'$, or whatever value we may adopt for the horizontal refraction—somewhere from 32′ to 40′ at sea-level. This is well known also as the equation for a fixed star in the horizon neglecting the refraction.

Having the values of t corresponding to the two values of the parallax, 88′ and 36′, we have the mean of these values of t corresponding to the parallax 62′; and, if to this mean we add one tenth of the difference between the two values of t first found, we have the value of t corresponding to the mean parallax of the Moon 57′.* The value of t corresponding to the actual parallax may now be interpolated between these special values if desired.

If the observer is at an elevation above his visible horizon, allowance should be made for the apparent dip of the horizon and the increase in refraction. We may denote the former by D and combine it with the refraction, so that we have

$$z = 90^\circ + (r + D - \pi) = 90^\circ + (r' - \pi)\,.$$

* The parallax of the Moon varies from 53′.9 to 61′.4, and the mean may be taken as 57′.2, which, for the present purpose, is sensibly the same as 57′.

A sufficiently approximate value of D may be obtained by the equation $D = 1'.00\sqrt{h}$; where h is the elevation in feet. * Of course, if the elevation is introduced, a change is made in the two fictitious values of the Moon's parallax for which the computations are made by (2). For an elevation of 100 feet, for example, we shall have, from the assumption $r' + s = \pi - r'$, the fictitious value $\pi = 108'$; and from the assumption $\pi - r' = 0$, we shall have the fictitious value $\pi = 46'$. The interpolation for the mean and actual values of the parallax will be modified accordingly.

Other fictitious values of the parallax and corresponding hour angles may occur under different circumstances, of which the reader can take account for himself. For instance, tables of semi-diurnal arcs, hour angles at rising or setting for celestial objects in general, may be at hand in which account is taken of the refraction but not of the semi-diameter of Sun or Moon. In such case the tabular value, taken according to the rule given above, will correspond to a parallax $\pi = 2r$ or $\pi = 72'$.

For occasional computations made without the aid of any previous tables of hour angles, it will be convenient to assume a special value of π in equation (2). Since it is advisable to employ equation (4) in any event, for a preliminary solution, we may put $\pi - r = 20'$ in equation (2); that is, corresponding to $r = 36'$, we shall have $\pi = 56'$. The actual parallax will never differ very much from this value, and the interpolation between the hour angles corresponding to the values $36'$ and $56'$ becomes very simple. Equation (2) then becomes

$$\cos t_1 = \tan\delta \tan\phi \left(\frac{[7.76475]}{\sin\delta \sin\phi} - 1 \right).$$

Since we have to deal, in general, with large hour angles in the present problem, the formulae given above are sufficiently accurate. For stations at, or very near, the equator, however, it will be necessary in all cases to resort to the ordinary formula

$$\sin \tfrac{1}{2} t = \sqrt{\{ \sin \tfrac{1}{2} [z + (\phi - \delta)] \sin \tfrac{1}{2} [z - (\phi - \delta)] \sec\phi \sec\delta \}}.$$

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* As an example of the effect of the dip of the horizon, the changes in the times of the setting of the Sun and Moon were computed for an observer at an elevation of 100 feet at latitude 45° north. The Sun at a declination of + 23°.5 sets $0^m.82$ later and the Moon at a declination of + 28°.5 sets $1^m.29$ later.

For a ready means of computing refractions at or near the horizon, see Professor Comstock's article, POP. ASTR. Vol. XVIII, p. 90.

The troublesome features of the computation of the times of rising or setting of the Moon, are due to the large motions of the Moon, in both right ascension and declination. The computer must go to the Ephemeris in any case for the positions of the Moon, and the employment of further data there given relieves him from further trouble as regards the former of the two motions. These data are contained in the columns "Greenwich Mean Time of the Transit of the Moon at Greenwich" and "Hourly Difference in the Local Mean Time of Transit for One Hour of Longitude", both of which are strangely ignored by some of the best and most recent text-books. The disposition of the second motion, that in declination, affecting the hour angle of the Moon at the horizon differently for different latitudes and different declinations of the Moon, is not so simple.

Here every computer must begin with an estimate of the declination of the Moon at the time of rising or setting; and this necessitates, first, an estimate of this time itself. The time may be expressed either in some standard time, as Greenwich mean time, or in local mean time. Everyone is familiar with the fact that the full Moon is rising when the Sun is setting; and the suggestion naturally occurs that this be taken as a starting point for making a sufficiently close estimate, at the outset, for the local mean time of moonrise and moonset, for any position of the Moon.

It is true, of course, in general, for all latitudes that the full Moon rises when the Sun sets. Neglecting the refraction and the deviation of the Moon from the ecliptic, it is also true for all latitudes that, with the Sun at either solstice, the Moon at first quarter rises when the Sun is on the meridian; and for all stations on the equator and with the Sun at either equinox, the Moon at first quarter rises when the Sun is on the meridian. For positions of the Sun at other points on the ecliptic, there will be a deviation from this relation of the Moon at first quarter; but this will not exceed two minutes of time for an observer on the equator and is entirely negligible in making an estimate of the time. In moving away from the equator, however, to north latitudes, for instance, the Moon's diurnal course above the horizon increases with north declination of the Moon and diminishes with south declination. This increase or decrease may be determined most simply for the present and with close enough approximation, by computing the hour angle of the Moon at the horizon for a given latitude of sta-

tion and declination of the Moon, neglecting the refraction and parallax, or by equation (4).

A first approximate time for the rising or setting of the Moon for stations at the equator may be derived by means of a rough interpolation between the Greenwich times of the four phases of the Moon given in the Ephemeris, by which the proportionate part of six hours is applied to the time of rising or setting for the next preceding phase. Then the additional application of the difference between the hour-angle, computed by (4), and six hours gives a sufficiently close preliminary local mean time for the rising or setting of the Moon. To facilitate this operation, the following two tables are given, the second of which was computed by equation (4). The times here considered are in apparent solar time; but the equation of time may be neglected in the preliminary estimate, and it does not come into account subsequently.

TABLE I. FOR THE EQUATOR.

Phase	Approximate Local Mean Time.	
	Rising	Setting
	h	h
New Moon	18	6
First Quarter	0	12
Full Moon	6	18
Last Quarter	12	0

TABLE II.

Latitude of Station	Declination of the Moon.						
	0°	5°	10°	15°	20°	25°	30°
0°	h	h	h	h	h	h	h
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	.0	0.0	0 0	0 1	0.1	0.2	0.2
10	.0	0.0	0.1	0.2	0.2	0 3	0.4
15	.0	0.0	0.2	0.3	0.4	0.5	0.6
20	.0	0.1	0.2	0.4	0.5	0.7	0.8
25	0.0	0.2	0 3	0.5	0.6	0.9	1.1
30	.0	0.2	0.4	0.6	0.8	1.1	1.3
35	.0	0.3	0.5	0.8	1.0	1.3	1 6
40	.0	0.3	0.6	0.9	1.2	1.5	1.9
45	.0	0.4	0.7	1 1	1.5	1.9	2.4
50	0 0	0.4	0.8	1.3	1.7	2 3	2.9
55	.0	0.5	1.0	1.5	2.1	2.8	3.7
60	.0	0 6	1.2	1.9	2.6	3.6	6.0
65	.0	0.7	1.5	2.3	3.4	6.0	
70	.0	0.9	1 9	3.1	6.0		
75	0.0	1.3	2.7	6.0			
80	0.0	2.0	6.0				

It will be evident in any particular case how the term from Table II is to be applied, or we may express the combination as follows:

Rising. Estimated time = (Table I) ± (Table II), Lat. and Decl. $\begin{cases} \text{opposite} \\ \text{the same} \end{cases}$ in sign.

Setting. Estimated time = (Table I) ± (Table II), Lat. and Decl. $\begin{cases} \text{the same} \\ \text{opposite} \end{cases}$ in sign.

From sixteen examples computed by the writer the average difference, without regard to sign, between this estimated time and that determined by the complete computation was only $0^h.09$ and the largest individual difference was $0^h.3$. These examples involved various phases of the Moon and a variety of positions in both latitude and declination. To illustrate the application of these tables, we may take the second example given at the close of this article, as follows:

HOBART. Longitude $9^h\ 49^m.4$ East; latitude 42° 53′.4 South.

Desired: the time of moonrise on the morning of Aug. 30, 1910, (in the night preceding).

From the Ephemeris.	Greenwich Mean Time of Transit
at Greenwich	Aug. 29, 20^h $21^m.2$
Long. × Diff. for 1 hour, −9.82×2.50,	−24 .6
Local Mean Time of Transit at Hobart, Aug. 29,	19 56 .6

From the Ephemeris. G. M. T. last quarter, Aug. 27.1; new Moon, Sept. 3.3.

First rough estimate of L. M. T. of moonrise at equator, Aug. 29, $13^h.7$ = Aug. 29.6

Interpolation term for Table I, $\frac{2.5}{7.2} \times 6^h = 2^h.1$.

Estimated local mean time of moonrise at Hobart, $12^h + 2^h.1$ (Table I) + $1^h.8$ (Table II) = Aug. 29, 15^h9.

A statement of the items of computation, together with their symbols, may now be presented for the general case as follows. It is amply adequate to compute to tenths of a minute in time, and four or five-place logarithms will suffice. Any prime meridian may be chosen for which an ephemeris is available; that of Greenwich is employed here, and the most convenient presentation of the data required seems to be given in the Greenwich portion of the American Ephemeris. But th

initial time-data will be found given to one more decimal place, if desired, in the "Moon Culminations" of the Ephemeris for the Washington meridian. Careful note must be made that in the Ephemeris and in this paper the hours are counted for the astronomical day, from 0^h at noon to 24^h at the next noon. Regard must be had to the signs of the declination of the Moon and of the latitude of the station, but the hour angle is regarded here as always positive. The abbreviations given will be employed against the corresponding numbers in the examples presented at the close of this article. The date at the start should be designated as A. M. or P. M. to distinguish the night for which the time is desired. For instance, with the Moon near the third quarter, and the time desired for the night before May 20, the date at the outset should be given as May 19, P. M. or May 20, A. M. It is advisable also to write down the date against each item of time, since in many cases the nominal date will change in the course of the computation.

The values of the parallax and of the "Hourly Difference" to be multiplied by the hour angle are entered, along with the other fixed data, in the first division of the computation, since a rough estimate of the hour angle suffices to determine these quantities with accuracy.

Station. Civil Date, A. M. or P. M. Rising or Setting, R or S.

I. Data of Computation.

Longitude of Station.
Standard Meridian from Greenwich. log sin ϕ.
Latitude of station, ϕ log tan ϕ.

G. M. T., Tr. = Greenwich mean time of upper transit of the Moon at Greenwich (astronomical date).

H. D. (1) = Difference in local mean time of transit for one hour of longitude, interpolated to the nearest hundredth of a minute of time for the halfway meridian between Greenwich and the station.

H. D. (2) = Difference in local mean time of transit for one hour of longitude, interpolated to the nearest hundredth of a minute of time, for the midway time between transit and rising or setting.

The Moon's horizontal parallax, π.

L.M.T., Tr. = Local mean time of transit at station.

G.M.T., Loc. Tr. = Greenwich mean time of transit at station.

II. Approximate Computation.

Est'd L.M.T., R. or S. = Estimated local mean time of rising or setting determined by aid of the Ephemeris times of the Moon's phases and Tables I and II.

Est'd G. M. T., R or S, by application of the longitude to the preceding.

Corresponding approximate declination of the Moon δ_o from the Greenwich ephemeris.

Approximate hour angle t_o from the equation

$$\cos (180^\circ - t_o) = \tan \delta_o \tan \phi.$$

Approximate interval to transit, $t_o' = t_o + t_o \times$ H.D. (2).

Approximate G.M.T., R or S = G.M.T., Loc. Tr. $\mp\ t_o'$.

III. Final Computation.

δ = Declination of the Moon corresponding to the preceding G. M. T., R. or S.

Special values of hour angles computed from the following equations.

Hour Angle	*Parallax*	
t_1	88′	$\cos (180^\circ - t_1) = \tan \delta \tan \phi \left(1 - \frac{[8.17971]}{\sin \delta \sin \phi} \right)$
t_2	36	$\cos (180^\circ - t_2) = \tan \delta \tan \phi,$
t_3	62	$t_3 = \frac{1}{2} (t_1 + t_2),$
t_4	57	$t_4 = t_3 + \frac{1}{10} (t_2 - t_1);$

where the square brackets indicate that the number enclosed is a logarithm, and where t_2 is always larger than t_1.

t = Hour angle interpolated, or extrapolated, from t_3 and t_4 for the actual parallax π.

t' = Interval to transit = $t + t \times$ H.D. (2) $= t + t_o'' \times$ H.D.(2) sensibly; where $t_o'' = t + t \times$ H.D.(2).

Check. $t' - t_o' < 5$ min. numerically.

L.M.T., R or S = L. M. T. Tr. $\mp\ t'$.

This is usually to be expressed as a civil date in the ordinary manner and reduced to standard time.

If a table of addition and subtraction logarithms is at hand, and the second term in the parenthesis in the second member of the equation for t_1 is to be added numerically, the logarithm of the entire parenthesis may be taken directly from the table as the function B corresponding to the logarithm of the fractional, second, term as the argument A.

If t' agrees with t_o' within five minutes, t' may be taken as

correct; if not, the computation of division III must in general be repeated. A corrected G. M. T., R or S will be obtained from the L. M. T., R or S just found and a new value of the declination will be looked out from the Ephemeris. But with the aid of Tables I and II, it seems practicable always to estimate the time of rising or setting within an hour, even in extreme cases, and much less in most cases; and a second computation will very rarely, if ever, be required.

If the computation is to be made for a number of dates at a given station, it will be of advantage to compute a double-argument table of hour angles with the declination of the Moon, from $-30°$ to $+30°$, as one argument and the parallax, from $54'$ to $62'$, as the other argument. Two columns for the parallax are ample, however, and $52'$ and $62'$ make convenient values for these as regards subsequent practice.

For convenience of reference, a statement of the items of computation by the ordinary method, as described in Young's General Astronomy, Art. 131, is also here given.

Station. Civil date, A. M. or P. M. Rising or Setting, R or S.
Longitude of station.
Standard Meridian from Greenwich.
Latitude of Station, ϕ log sec ϕ.

Est'd L. M. T., R or S = Estimated local mean time of rising or setting.

Est'd G. M. T., R or S = Estimated Greenwich mean time, from the preceding.

Corresponding right ascension of the Moon α, declination δ, and parallax π from the Greenwich Ephemeris.

Zenith Distance, $z = 90° + r - \pi$, for the center of the Moon.
Hour angle t by the equation

$$\sin \tfrac{1}{2} t = \sqrt{\left\{ \sin \tfrac{1}{2} [z + (\phi - \delta)] \sin \tfrac{1}{2} [z - (\phi - \delta)] \sec \phi \sec \delta \right\}}.$$

t always positive.*
Sid. T., R or S. = Sidereal time of rising or setting $= \alpha \mp t$.
L. M. T., R or S = Corresponding local mean time.

If this last time agrees with the Est'd L. M. T., R or S within five minutes, a second computation is unnecessary, and the time last obtained should be expressed as a civil date and

* It may be noted here that, since the sum of the two quantities within the two pairs of square brackets is nearly 90°, the corresponding logarithms will in general fall upon the same page of the tables.

reduced to standard time if required. If the agreement is not so close, the L. M. T. obtained must be reduced to G. M. T. and the computation repeated. A third computation should never be required for stations in moderate latitudes.

In occasional computations the latter, the ordinary, method is probably the most readily taken up and perhaps the safer. When the result is of some importance, however, it is highly desirable to compute by both methods as a control. When a series of results are to be computed for a given station the former method is distinctly superior, in point of economy, especially when the proper tables for the Sun are at hand pertaining to the given station. In such a series, too, the values of the hour angles t_1 and t_2, for the first fictitious values of the parallax, will have a systematic difference which will make a good control. The aid of Table II in forming a close estimate of the required time, may be employed, of course, in either case; but the suggestion arose in connection with Frisby's method, and such a table would hardly be at hand for an occasional computation by the ordinary method.

The advantages of the first method presented in this paper, that devised by Professor Frisby, may be summarized as follows:

1. The only variable entering into the trigonometric computation is the declination of the Moon, and that occurs only twice.

2. A very simple computation furnishes two values of the hour angle between which a direct interpolation may be made to allow for the actual parallax.

3. Tables of semi-diurnal arcs for celestial objects in general, or special tables for the Sun, may be employed directly to determine closely approximate values for the Moon.

4. With the aid of two different tables of the sort just mentioned, no trigonometric computation at all is required, and with one such table alone none is required beyond the multiplying together of two tangents.

5. With the aid of tables I and II of this article the complete computation need be made only once.

6. If the computer writes down nearly all the items of computation, which is the safe thing to do, the first method has forty-one to forty-five items, after the position of the station is entered; while the second method has fifty-three items, of which about one half are due to the solution of the second approximation; this in general is required.

To illustrate the application of the methods described above, the following examples are given, involving a variety of conditions, as regards geographical position and position of the Moon. The first of these examples is worked out by both methods, and in the second the value 56′ is employed for the first preliminary parallax. The corresponding abbreviations or symbols are given at the left-hand side of each page. The examples are given just as they happened among a number that were computed.

STATION	CAPE FAREWELL	HOBART
CIVIL DATE	1909, OCT. 7, A.M., R.	1910, AUG. 30, A.M., R.
I	I	I
Long.	$2^h\ 56^m.12\ W = +2^h.94$	$9^h\ 49^m\ 4\ E = -9^h.82$
St'd Merid.	3^h West of Greenwich	10^h East of Greenwich
Lat. ϕ	$+59°\ 49'.0$	$-42°\ 53'.4$
Log sin ϕ	9.93673	9.8329_n
tan ϕ	0.23536	9.9680_n
G. M. T., Tr.	Oct. 6, $18^h\ 50^m.5$	Aug. 29, $20^h\ 21^m.2$
H. D. (1), H. D. (2),	$2^m.20\quad 2^m.22$	$2^m.50\quad 2^m.47$
Parallax π	56′.2	58′.5
L. M. T., Tr.	Oct. 6, $18^h\ 57^m.0$	Aug. 29, $19^h\ 56^m.6$
G. M. T., Loc. Tr.	Oct. 6, 21 53 .1	Aug. 29, 10 7 .2
II	II	II
Est'd L. M. T. of R (S).	Oct. 6, $9^h.4$	Aug. 29, $15^h.9$
Est'd G. M. T. of R (S).	Oct. 6, 12 .3	Aug. 29, 6 .1
Approx. Decl. δ_o	$+25°\ 6'$	$+26°\ 41'$
Approx. H. A. t_o	$9^h\ 34^m.6$	$4^h\ 8^m.7$
$t_o \times$ H. D. (2)	21 .3	10 .2
Approx. Int. to Tr., t'_o	9 55. 9	4 18.9
Approx. G. M. T. of R (S.),	Oct. 6, $11^h\ 57^m.2$	Aug. 29, $5^h\ 48^m.3$
III	III	III
Decl. δ	$+25°\ 7'.8$	$+26°\ 41'.4$
HA. Par.	h m	Par. h m
t_1 88′	9 22.6	56′ 4 6.3
t_2 36	9 35.0	36 4 8.6
t_3 62	9 28.8	. .
t_4 57	9 30.2	. .
t π	9 30.2	58.5 4 6.0
$t \times$ H.D. (2)	21.1	10.1
t_o''	9 51.3	4 16.1
$t_o'' \times$ H. D. (2)	21.9	10.6
Int. to Tr. t'	9 52.1	4 16.6
L.M.T., of R, (S).	**Oct. 6, 9 4.9**	**Aug. 29, 15 40.0**
St'd. T. of R,(S).	**Oct. 6, 9 1.0 P.M.**	**Aug. 30, 3 50.6 A.M.**

Supplementary Computation

$\log \tan \delta_o$		9.67065	9.7012
$\tan \phi$		0.23536	9.9680_n
$\cos (180° - t_o)$		9.90601	9.6692_n
t_o		143° 38′.9	62° 10′.1
$\log \sin \delta$		9.62806	9.6524
$\sin \phi$		9.93673	9.8329_n
$\sin \delta \sin \phi$		9.56479	9.4853_n
$\sin 52'$		8.17971	[sin 20′] 7.7648
$\log (2)$	A	8.61492	8.2795_n
(2) (Number)		+ 0.041202	
$1-(2)$		+ 0.958798	
$\log [1-(2)]$	B	9.98173	0.0082
$\log \tan \delta$		9.67124	9.7013
$\tan \phi$		0.23536	9.9680_n
$\cos (180° - t_1)$		9.88833	9.6775_n
$\cos (180 - t_2)$		9.90660	9.6693_n
t_1		140° 38′.9	61° 35′.0
t_2		143 45 .3	62 9 .7

STATION	CAPE FAREWELL.
CIVIL DATE	1909, OCT. 7, A.M., R.
Long.	2^h 56^m 12 W.
St'd. Merid.	3^h West of Greenwich
Lat. ϕ	+ 59° 49.′0
Log. sec ϕ	0.29863

	First Approximation	*Second Approximation*	*Third Approximation*
Est'd L.M.T. of R(S).	Oct. 6, 12^h 0	9^h 14^m.78	9^h 6^m.46
Est'd G.M.T. of R(S).	Oct. 6, 14 9	12 10 .90	12 2 .58
Approx. R. A.	7^h 42^m.6	7 36 .22	7 35 .89
Approx. Decl.,	+24° 57′.5	+25° 6′.4	+25° 6′.9
Parallax π	56′.1	56′.2	56′.2
z	89° 39′.9	89° 39′.8	89° 39′.8
$\phi - \delta$	+ 34 51 .5	+ 34 42 .6	+ 34 42 .1
$z + (\phi - \delta)$	124 31 .4	124 22 .4	124 21 .9
$z - (\phi - \delta)$	54 48 .4	54 57 .2	54 57 .7
$\frac{1}{2}[z + (\phi - \delta)] = (1)$	62° 15′.7	62° 11′.2	62° 11 .1
$\frac{1}{2}[z + (\phi - \delta)] = (2)$	27 24 .2	27 28 .6	27 28 .8
$\log \sin (1)$	9.94698	9.94668	9.94667
$\sin (2)$	9.66300	9.66406	9 66411
$\sec \phi$	0.29863	0.29863	0.29863
$\sec \delta$	0.04258	0.04310	0 04313
	9.95119	9.95247	9 95254

	First Approximation	*Second Approximation*	*Third Approximation*
log sin ½ t	9.97560	9.97624	9.97627
½ t	70° 58′.4	71° 13′.20	71° 13′.80
t	141 56 .8	142 26 .40	142 27 .60
t	9h 27m.8	9h 29m.76	9h 29m.84
Sid. T. of R (S).	22 14 .8	22 6 .46	22 6′ .05
Gr. Sid. T. Mean Noo	Oct. 6, 12h 58m.02		
Accel. for Long.	+0 .48		
Loc. Sid. T. Mean Noon	Oct. 6, 12 58 .50	12 58 .50	12 58 .50
Sid. Interval	9h 16m.30	9h 7m.96	9h 7m.55
Accel.	1 .52	1 .50	1 .50
L.M.T. of R (S).	Oct. 6, 9 14 .78	9 6 .46	**Oct. 6, 9 6.05**
St'd. T. of R (S).			**Oct. 6, 9 2.2 P.M.**

STATION	WELLINGTON.
CIVIL DATE	1909, MAR. 23, P. M., S.
Long.	11h 39m.1 E
St'd. Merid.	11h 30m East of Greenwich
Lat. ϕ	−41° 16′.5
Log. sec ϕ	0.1240

	First Approximation	*Second Approximation*
Est'd L.M.T. of (R) S.	Mar. 23, 7h.5	7h 11m.2
Est'd G.M.T. of (R) S.	Mar. 22, 19 .8	19 32 .1
Approx. R. A.	1h 31m.9	1h 31m.58
Approx. Decl., δ	+5° 5′.5	+5° 1′.4
Parallax π	60′.8	60′.8
z	89° 35′.	89° 35′.2
$\phi - \delta$)	−46 22 .	−46 17 .9
$z + (\phi - \delta)$	+43 13 .	+43 17 .3
$z - (\phi - \delta)$	135 57 .	135 53 .1
½$[z + (\phi - \delta)]$ =(1)	21° 36′.	21° 38′.6
½$[z + (\phi - \delta)]$ =(2)	67 58	67 56 .6
log sin (1)	9.5663	9.5668
sin (2)	9.9671	9.9670
sec ϕ	0.1240	0.1240
sec δ	0.0017	0.0017
	9.6591	9.6595
log sin ½ t	9.8296	9.8298
½ t	42° 29′.4	42° 30′.9
t	84 58 .8	85 1 .8
t	5h 39m.9	5h 40m.12
Sid. T. of (R) S.	7 11 .8	7 11 .70
Gr. Sid. T. Mean Noon	Mar. 23, 0h 1.m33	
Accel. for Long.	−1.91	
Loc. Sid. T. Mean Noon	Mar. 23, 23 59.42	23 59.42
Sid. Interval	7h 12m.4	7h 12m.28
Accel.	1 .2	1 .18
L.M.T. of (R) S.	Mar. 23, 7 11 .2	**Mar. 23, 7 11.10**
St'd. T. of (R) S.		**Mar. 23, 7 2.0 P.M.**

It is not evident how the difference of $1^m.2$ arises between the two methods in the first example, that for Cape Farewell. A second computation by the first method gave the Standard Time of Rising as $9^h\ 1^m.2$; and another computation in which the data of the "Moon Culminations" of the ephemeris for the Washington meridian were employed gave $9^h\ 1^m.14$. A fourth computation by the second method gave $9^h\ 2^m.13$; so that the difference persists. But a difference of a minute or two at such a high latitude and with such a position of the Moon is nothing to quarrel over; and a moderate deviation of the temperature and barometer from the normal will make a difference there of two minutes or more anyway in the time of rising.

Washburn Observatory, Madison, Wisconsin.

FURTHER CONSIDERATIONS ON THE ORIGIN OF THE ZONE OF ASTEROIDS AND ON THE CAPTURE OF SATELLITES.*

T. J. J. SEE

In Volume II of my "Researches on the Evolution of the Stellar Systems," 1910, which has just been published, I have treated at some length of the most important problems connected with the origin of the solar system, and have shown that as regards mode of origin the asteroids are connected with the periodic comets and have been gathered within Jupiter's orbit by the action of that great planet. This conclusion had been anticipated to some extent by the late Professor Stephen Alexander, of Princeton University, as far back as 1851, and more recently by the late Professor H. A. Newton, of Yale, and by the late M. Callandreau, of the Paris Observatory. The inferences of Newton and Callandreau resulted from their mathematical investigations of the perturbations of Jupiter upon small bodies crossing his orbit. Fortunately the weight of these eminent authorities is such that we need not dwell on the mathematical methods of reasoning employed. Our present aim is rather to examine briefly the consequences which follow from this theory, as developed in the second volume of my "Researches,"and to make somewhat clearer the

* *Reprinted from Proceedings American Philosophical Society, Vol. xlix., 1910.*

significance of certain observed phenomena of the solar system, by an argument so brief and so much to the point that even a layman may grasp it without difficulty.

1. It was pointed out by Oppolzer in 1880* that the resistance to two homogeneous spheres revolving in a discontinuous medium of cosmical dust is inversely as their radii, and therefore relatively very large for a small body and very small for a large one.† The secular effect of such a cause, therefore, is to make the small body approach the Sun very rapidly, while it scarcely modifies the mean distance of the large body, the latter change being so small that it often may be neglected entirely.

2. Now if we contemplate the arrangement of the orbits of the asteroids in the solar system, we find them grouped almost entirely within Jupiter's orbit, in accordance with the mathematical investigations of Newton and Callandreau, and moreover spread over the entire zone from Jupiter to Mars, and even extending beyond these limits. Thus Eros has a mean distance slightly less than that of Mars, while the Achilles group of asteroids projects beyond the orbit of Jupiter. How much wider the zone may hereafter be found to be, it is difficult to predict.

3. Since the asteroids have been thrown just within Jupiter's orbit by the successive actions of that great planet, and subsequently had their mean distances so decreased with the lapse of ages as to carry them down to the orbit of Mars, it follows that this spreading of the asteroids over such a wide zone affords a clear and unmistakable illustration of the effects of resistance and collisions—these small bodies having approached the Sun much more rapidly than the giant planet Jupiter which gathered them in. No other interpretation can be given to the great width of the asteroid zone. For the perturbative action of Jupiter could throw the asteroids but slightly within his own orbit, and the great decrease in the mean distances of many of them must be accounted for in some other way. We conclude, therefore, that the more rapid dropping of the asteroids towards the Sun illustrates the secular effects of resistance in the form of cosmical matter, such as meteoric swarms and comets, which must occasionally be encountered by the asteroids as well as by Jupiter. In the long run the secular effects of collisions with comets and similar *isolated*

* Cf. *A. N.*, 2314 and 2319.

† Cf. my "Researches," Vol. II., p. 293.

bodies is exactly the same as the effects of a medium of cosmical dust of nearly *continuous character*, so that we need not dwell on the character of the medium.

4. It is important to notice that as the small masses approach the center most rapidly, they would tend in time to overtake the larger planets nearer the Sun. Thus the Moon may have had originally a greater mean distance than the Earth, but by degrees it was brought so near our planet that it passed under the Earth's control and became a satellite. A similar conclusion holds for all the other satellites of the solar system. Besides crossing over the orbits of the larger planets, owing to larger eccentricity, these smaller bodies were originally at greater distances than their several planets, and in approaching them by degrees were at length brought within the range of the planetary attraction and captured, as explained in Volume II of my "Researches on the Evolution of Stellar Systems."

5. In the PROCEEDINGS of this society, 1910, p. 213, we have explained the process of capture by a direct and simple method of reasoning, and in view of the considerations just adduced, one cannot doubt that this represents essentially the process of nature. The lesson taught by the great width of the zone of the asteroids is so very significant that it may serve as a practical demonstration of certain tendencies in the physical universe. The same conclusion may be otherwise verified, from a new and independent point of view, as follows.

It is shown by the exact data calculated from Babinet's criterion that the planets never could have been detached or thrown off from the central mass of our system, but were formed at great distances and have gradually neared the Sun, as its mass increased and they revolved in the nebular resisting medium and gathered up more and more cosmical dust.

6. Since, therefore, the solar nebula as a whole did not rotate fast enough to detach the planets, or even exert a sensible centrifugal force, but they were originally independent nuclei formed in the remoter parts of the nebula, at a great distance from the center, it will be doubly obvious that these insignificant secondary nuclei in the outer parts of the nebula could not have rotated rapidly enough to detach their satellites. This is emphasized also by the retrograde motions of the outer satellites of Jupiter and Saturn, which are entirely inconsistent with any theory of detachment. Such a view would be nothing less than absurd. The relatively greater energy of axial rotation

of some of the planets is to be explained by the capture of nebulous matter circulating as a vortex in the powerful field of the Sun's attraction, owing to its immense mass, which gives the particles impinging against the planet great relative moment of momentum.

7. The column of the accompanying table designated "centrifugal force" gives the fractional part of the centrifugal force due to rotation, when the central bodies are expanded to fill the orbits of their attendant bodies as imagined by Laplace. In this table the unit in each case is the amount of centrifugal force required to set the body revolving in its present orbit. The excessively small value of the centrifugal force due to the rotation of the expanded central mass is very remarkable; and emphasizes strongly the untenability of the view that the attendant bodies were thrown off. Nothing more misleading than this traditional view ever became current in the literature of science; and yet it still circulates in all old works on astronomy, and probably it will take many years to get it eliminated from the current thought of our times.

8. There is another impressive way of illustrating the untenability of the now abandoned detachment theory, as follows: It is shown in works on celestial mechanics that

$$v^2 = k^2(1 + m)\ (2/r - 1/a). \qquad (1)$$

where k^2 is the constant of attraction, m the mass of the attendant body, that of the central mass being unity, r is the radius vector, a the semi-axis major, and v the velocity. This gives for an attendant body of insensible mass

$$a = \frac{1}{\frac{2}{r} - \frac{v^2}{k^2}} \qquad (2)$$

As the orbits of the planets and satellites are essentially circular, we may put $r = a = 1$; and then since

$$a = \frac{1}{\frac{2}{r} - \frac{v^2}{k^2}} = 1,$$

it follows that these units $v^2/k^2 = 1$. If instead of the velocity appropriate to carry the attendant body around in its nearly circular orbit, we substitute in (2) the fractional values of v^2/k^2 given in the above table, as due to the rotation of the central mass postulated by Laplace, we shall find that in all cases the semi-axis major of the new orbit is about one-half

that of the existing orbit. The largest value results from the inner ring of Saturn, where the equation would give $a=1/1.86=0.54$, the value of v^2/k^2 in this case being about 0.14.

TABLE OF DATA RELATING TO THE SOLAR SYSTEM.

Planet	Centrifugal Force, calculated from data of Babinet's criterion, present orbital centrifugal force being unity.	Density of Central Body, when expanded to fill orbit, that of atmospheric air at sea level being unity.
Mercury	0.000000253	0.001776
Venus	0.000000134	0.0002723
The Earth	0.000000098	0.0001029
Mars	0.000000064	0.00002913
Ceres	0.000000035	.....
Jupiter	0.000000019	0.000000732
Saturn	0.000000010	0.000000118
Uranus	0.0000000051	0.0000000146
Neptune	0.0000000032	0.0000000038

9. The obvious meaning of this result is that if the planets and satellites were projected along the tangents of their present orbits with such small squared velocities as shown in the table, they not only would not pursue their present paths, but would in each case fall towards the centers and describe orbits with

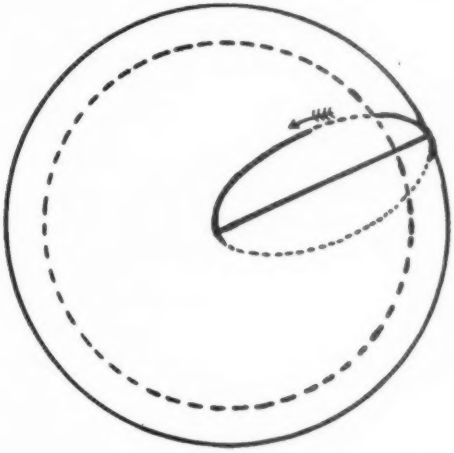


Fig. 1. Illustration of the motion of a particle projected along the inner edge of Saturn's dusky ring with velocity corresponding to planet's axial rotation when expanded to fill the ring. Pointed circle shows present dimensions of planet.

semi-axes just about one half. In other words, the projected satellites would pursue very elongated ellipses having their aphelia at the existing orbits, but their perihelia penetrating the central masses about which they now revolve. *In no case would over half a revolution be possible without collision because the projected satellites would fall almost straight to the center and be absorbed in the central mass.*

If we compute the densities of the Sun when expanded to fill the orbits of the planets, and of the several planets when expanded to fill the orbits of their respective satellites, we shall get the results given in the last column of the table. In considering this table it is sufficient to recall that an atmospheric pressure of 0.1 of a millimeter or a density of 1/7600 that of air is a very high vacuum; and since no greater hydrostatic pressure than this could be exerted from the center outward in case of most of the planets and many of the satellites as they fall unsustained by centrifugal force towards their dominant central masses, we see that these attendant bodies would in all cases fall practically without obstruction, and collision would in every case occur at the end of half a revolution. Could a more complete overthrow of the traditional detachment hypothesis of Laplace be imagined?

10. This affords an impressive illustration of the fallacy of the Laplacean theory of the origin of the planets and satellites; and the only way we can explain the failure to detect this contradiction long ago is by the fact that Babinet's criterion seems to have been totally overlooked till taken up by the writer in 1908.

11. Since the attendant bodies could not be thrown off by rotation, and could not form where they now revolve out of mere scattered dust, owing to the feebleness of the mutual gravitation of such particles, under the powerful dispersive tidal action of the adjacent central masses, it follows incontestably that the planets and satellites have all been captured and added on from without. And we have explained the method of capture by simple and general considerations which make it certain that this process represents the true law of nature.

12. Any one who calculates the moment of momentum of orbital motion of the satellite such as the Moon, which is 4.8 times larger than the present total moment of momentum of the Earth's axial rotation, will perceive how powerfully the rotation of a planet may be accelerated by the impact of satel-

TABLE OF DATA RELATING TO THE SATELLITE SYSTEMS.

Planet	Satellite	Centrifugal Force, calculated from data of Babinet's criterion present orbital centrifugal force being unity.	Density of Central body, when expanded to fill orbit, that of atmospheric air at sea level being unity.
The Earth.....	The Moon	0.00005657	0.01965
Mars.....	Phobos	0.001612	1151.
	Deimos	0.000644	73.05
Jupiter.....	V	0.034408	58.93
	I	0.014694	4.66
	II	0.009277	1.15
	III	0.005820	0.285
	IV	0.003323	0.0523
	VI	0.0005416	0.000232
	VII	0.0005217	0.000208
	VIII	0.0002254	0.0000169
Saturn.....	Inner Ring	0.1435	
	Mimas	0.048254	16.45
	Enceladus	0.037651	7.61
	Tethys	0.030436	4.11
	Dione	0.023772	1.96
	Rhea	0.017017	0.717
	Titan	0.0073449	0.0576
	Hyperion	0.0070716	0 0324
	Iapetus	0.0025205	0.00232
	Phoebe	0.0006962	0.000049
Uranus.....	Ariel	0.0055888	2.40
	Umbriel	0.0040111	0.88
	Titania	0.0024454	0.200
	Oberon	0.0018287	0.082
Neptune.....	Satellite	0.0017177	0.43

lites against its surface. To be sure, the case of the Moon is by far the most extreme in the solar system, owing to its large mass, but the tendency is the same everywhere, and really rapid rotations can be acquired only by the gathering in of quantities of satellites in the Sun's field of force by large planets, as in the observed cases of Jupiter and Saturn.

The planets were formed at great distances from the Sun, where the field of attraction would be much feebler than in their present situations; and hence nebulous matter collecting to such secondary centers in the outer parts of our nebula would give but feeble rotations of these masses about their axes; so that at no time in the past history of the solar system could a planet have rotated with sufficient rapidity to develop an appreciable tendency to detach a satellite. Such an hypothesis is wholly untenable, because it is found by calcu-

lation that the rapid rotations develop only when the planets are comparatively near the Sun, and the relative moment of momentum of impinging particles therefore large.

Accordingly the simple considerations here adduced confirm from another independent point of view the results already obtained in second volume of my "Researches"; namely, that the Moon and other satellites are merely captured planets, originally describing independent orbits about the Sun, and show that the Capture Theory unquestionably is an ultimate law of nature.

U. S. Naval Observatory,
Mare Island, Calif., Oct. 17, 1910.

HALLEY'S COMET.

FREDERICK SLOCUM.

How much longer can Halley's comet be followed? This is about the only question of interest left to be asked in regard to the historic comet. At the former apparition, 75 years ago, it was visible for approximately 650 days. At the present apparition it was discovered 249 days before perihelion passage. It has already been followed over 300 days since perihelion, and it is by no means at the limit of visibility yet.

When discovered by Wolf, September 11, 1909, it was estimated to be of the sixteenth magnitude. It was then 318 million miles from the Sun and 331 million miles from the Earth. On March 19, 1911, the date of the accompanying photograph (Plate X, Frontispiece), the comet was 428 million miles from the Sun and 344 million miles from the Earth. From its appearance on the photograph its magnitude is estimated to be between fourteen and fifteen. A visual observation by Professor Barnard on the same night with the 40-inch telescope made it 13.5, showing that it was much brighter than when discovered, in spite of the fact that it was 110 million miles farther from the Sun and thirteen million miles farther from the Earth than on the date of discovery.

If it maintains its present rate of decrease in brightness, it will undoubtedly be followed by the more powerful instruments until lost in the rays of the Sun in midsummer, and may possibly be picked up again in September or October in the morning sky. It will be in conjunction with the Sun in August.

The photograph, reproduced in Plate X, was taken with the 24-inch reflector of the Yerkes Observatory, with an exposure of one hour. The comet appears as a fuzzy trail near the point of the arrow. Its rate of motion at that time was 48″ per hour in a northwesterly direction. The bright star to the southeast of the comet is BD — 12°.3162, a double star, magnitude 7.3; and the brightest of the stars north of the comet is BD — 12°.3161, magnitude 7.5.

The position of the comet, as obtained by Professor Barnard with the 40-inch telescope, was R.A. = $10^h\ 20^m\ 48^s.91$, Dec. = —12° 36′ 7.″5 at $15^h\ 24^m\ 25^s$ G. M. T., March 19, 1911. It is moving slowly northwestward through the constellation Hydra, and will enter Sextans early in April.

Yerkes Observatory, Mar. 28, 1911.

THE SUN AS A STAR.*

PERCIVAL LOWELL.

The relative size of our Sun among his peers is a subject about which much has been written from very questionable data. The enormous masses found for certain stars from parallax, light-magnitude or proper motion have always seemed to me calculated to inspire the greatest distrust. The only reliable premises are such as may be derived from double stars whose orbits have been fairly conclusively ascertained. Binary stars afford our sole means of learning directly the masses concerned. For to suppose that their motion is due to a force other than gravity is to suppose that the force depends upon its orientation which is not a reasonable supposition.

If we take m_1 and m_2 for the respective masses of the constituents of a binary, a the semi-major axis of the system, P its period and π its parallax, we have for the determination of the sum of the masses the equation:

$$m = m_1 + m_2 = \frac{\left(\frac{a}{\pi}\right)^3}{P^2}$$

Since the parallax, π, of a star is the shift in its apparent place due to the changed position of the Earth in her orbit,

* Paper read by Mr. Lampland before the American Association for the Advancement of Science at their meeting in December, 1910.

the quantity $\frac{a}{\pi}$ gives the semi-major axis of a binary star's orbit in terms of the Earth's, that is in astronomical units.

If we take the semi-major axis of the Earth's orbit for the unit of distance, its orbital period for the unit of time and the mass of the Sun for the unit of mass, we shall have the combined mass m of the binary, $m_1 + m_2$, expressed by the equation in terms of the Sun's mass. If therefore we can find π we are in a position to learn the binary's mass as compared with the Sun's.

Some of the binaries whose orbits have been found have also shown a measurable parallax. With them we are therefore in posession of the data necessary to the discovery of their masses as compared with that of our own Sun. A preliminary article on this subject has recently appeared by Mr. R. G. Aitken; I call it preliminary by courtesy because it adroitly misses the conclusions deducible from the data.

Professor J. C. Kapteyn has recently published in No. 24 of the Publications of the Astronomical Laboratory at Gröningen a list of parallax determinations. Among the stars thus localized the following turn out to be binaries whose orbits have been calculated. For the most recent and most reliable of these orbits I am indebted to my friend, the well-known double star authority, Professor S. W. Burnham of the Yerkes Observatory. I may add that without knowing the outcome of this investigation he expressed himself with regard to parallax in terms which have proved singularly justified.

BINARIES.

TABLE I.

Star	Magnitude	P (years)	a ″	″ π	m_1+m_2	Computer
Ceti 82 (Bode) β 395	6.1 — 6.3	24.0	0 66	.360	0.01	Aitken
		345.6	10.10		1.06	
μ Cassiopeiae	4.0 — 7.5			.201		
		507.6	12.21		0.87	
γ Andromedae (BC)	5.0 — 6.2	55.0	0 346	.007	39.92	Hussey
400^2 Eridani (BC)	9.1 — 10.8	180.0	4.7?	.174	0.64	Doolittle
		16.6	0.24			See
β 883	7.0 — 7.0			—.023		
		17.0	0.19			Lohse
β 552	7.0 — 10.0	56.	0.53	.007	138.41 ×	
Sirius	—1.6 — 9.0	49.3	7.55	.376	3.33	
		346.8	5.76		72.38	
Castor	2.7 — 3.7			.028		195.80
		249.3	7 58		319.22 ×	
Procyon	0.5 — 13.	40.	5.8	.324	3.59	
Σ 3121	7.5 — 7.8	34.0	0.67	.008	506.35	See

Star	Magnitude	P (years)	a ″	π ″	m_1+m_2	Computer
		60.00	2.51		0.76	See
ξ Ursae Maj. (Mizar)	4.0 — 4.9			.179	0.55	
		59.59	1.90		0.34	Norlund
γ Virginis Σ 1670	3.0 — 3.0	194.0	3.99	.058	8.64	See
β 612	6.0 — 6.0	34.4	0.31	.260	.001	Aitken
α Centauri	0.3 — 1.7	81.1	17.70	.759	1.93	See
0Σ 298	7.0 — 7.3	52.0	0.80	.046	1.94	See
ξ Herculis	3.0 — 6.5	35.00	0.50	.142	0.84	See
26 Draconis β 962	5.5 — 10.1	197.	1.90	.088	0.26×	
μ Herculis	10.5 — 11.0	45.0	1.39	.106	1.11	See
70 Ophiuchi	4.1 — 6.1	88.39	4.55	.168	2.54	See
β 648	6.0 — 9.5	50.8	1.22	.018	123.47×	
β Delphini β 151	4. — 6.	27.66	0.37	—.010		
δ Equulei 0Σ 535	4.5 — 5.0	5.70	0.25	.067	1.60	Hussey
τ Cygni	4.9 — 7.4	48.45	0.77	.128	0.09	Lohse
κ Pegasi β 989	4.8 — 5.3	11.42	0.42	.028	26.17	See
β 80	8.2 — 9.1	63.5	0.63	.021	6.70×	
85 Pegasi β 733	6.0 — 10.	24.0	0.89	.067	2.39	Burnham

P = Period; a = semi-major axis; π = parallax.

A cursory glance at this table suffices to show that it is the binaries of very small parallax that give large masses. This is enough to point one to the path. If instead of taking the mean of all we divide them into groups according to parallax we find:

TABLE II.

MEAN MASS.

IN TERMS OF THE SUN.

	″	″ ″	″ ″	″ ″	″ ″	″ ″	″ ″	″ ″
π = over	4	.2—.4	.1—.2	.067—.1	.033—.067	.017—.033	.007—.017	
	1.93	1.58	.96	1.42	5.29	88.03	228.23	

Here the relation between parallax and mass is striking. Now let us examine the equation

$$m_1 + m_2 = \frac{\left(\frac{a}{\pi}\right)^3}{P^2}.$$

This equation may be affected by systematic errors of observation in either a, π or P. Systematic errors must occur in P from the fact that binaries where the period is long have not yet been observed a sufficient time to enable their orbits to be computed. Other things equal, those of short period have. Consequently as the mass depends inversely on the square of the period, a systematic error is here introduced tending to magnify the apparent mean value of the mass.

The semi-major axis introduces another limitation. Below a

certain value the semi-major axis becomes too small for visual observation. All such orbits are therefore necessarily excluded for any given period and therefore in the mean for all periods. The smaller *a*, the smaller the mass, other factors the same. Consequently by this omission the apparent mean is also increased above the true one. Both therefore on the score of the period and on that of the semi-major axis the recorded mean of the mass must fall below the fact. Our results, then, will certainly not err by being too small from errors thus due the period and the major axis.

Inspection next shows that the period cannot account for the increased mean mass with diminishing parallax. For the long period binaries tabulated occur as much among the greater as among the smaller parallaxes. With regard to the major axes we find on tabulation the following values:

SEMI-MAJOR AXIS.

π = over	.4		.2—.4		.1—.2		.1—.067		.067—.033		.033—.017	.017—.007
	17″.70		5″.10		2″.37		1″.01		2″.40		2″.23	″.52

Down to $\pi = .067''$ the axes diminish in something like the proportion we should expect from the parallax. Beyond this they do not, showing that from this point they tend unduly to increase the apparent mean. But they do not do so *pari passu* with the resulting masses and at the last actually fall off.

We thus see that the prime cause for the rise in the curve of mean mass value is due to errors of parallax. Since we cannot suppose the stars nearest us disparagingly small. From which we perceive that from $\pi = 0''.067$ down (see both Table I and Table III) the parallax is unreliable. This investigation thus discloses that any parallax less than $\pi = 0''.067$ is untrustworthy, a conclusion of import in such investigations.

Turning now to the resulting value thence deducible for the mean mass of a binary system we find from Table I:

TABLE IV.

MEAN MASS OF BINARY.

for all over

π	″.4+	″.2+	″.1+	″.067+	″.033+	″.017+	″.007+
	1.93	1.64	1.30	1.32	1.79	18.22	44.47

If we eliminate those marked with a cross in Table I of which Burnham considers the orbit unreliable, we get:

TABLE V.
MEAN MASS OF BINARY. EXPURGATED.
all over

π	″.4+	″.2+	″.1+	″.067+	″.033+	″.017+	″.007+
	1.93	1.77	1.33	1.43	1.95	3.46	33.43

η Cassiopeiae is retained because, though the period is very uncertain, all the orbits for the binary give nearly the same mass.

An improvement is noticeable but the large values for the small parallaxes are still evident. In consequence we find that values of the mass found from parallaxes less than ″.067 must be discarded. This gives for the value for the mean mass of the binary systems deduced from all those which can be relied on as approximately correct:

Mass of binary = 1.35 approx. times the Sun's mass.

We must furthermore remember that this result is more likely to be diminished than increased for the reasons previously given.

From this investigation we may sum up the results as:

1. Parallaxes beyond 0″.067 are too small to be trustworthy;

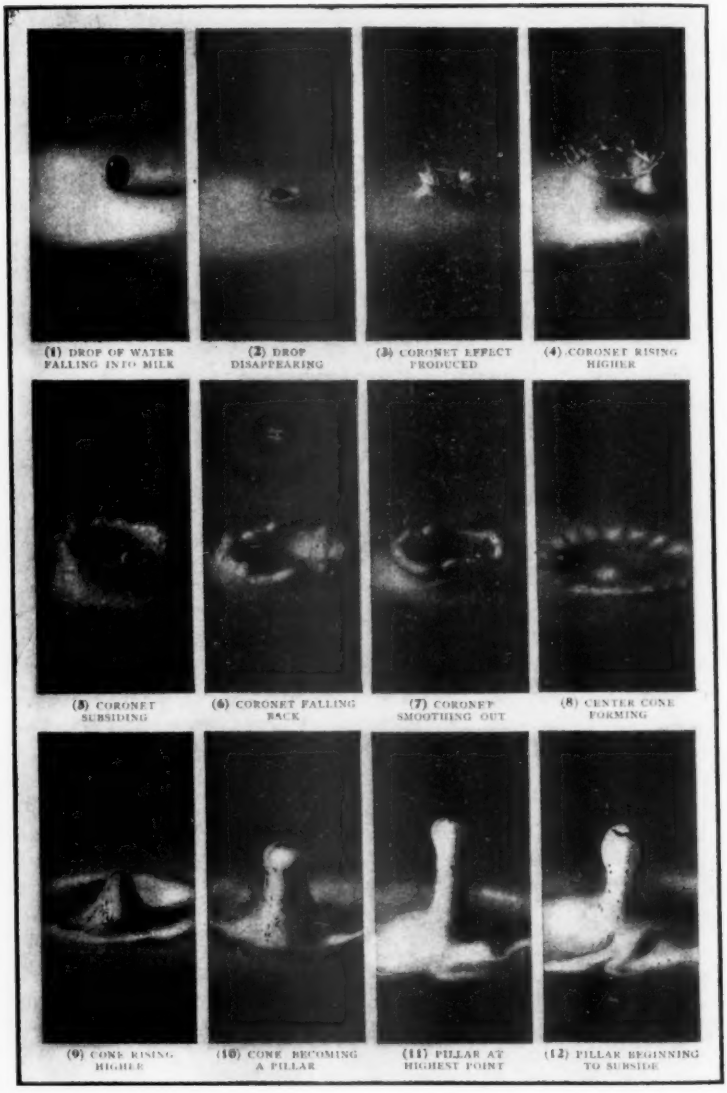
2. The masses of those stars for which alone we have dependable data is in the mean almost exactly the same as that of our Sun.

Boston, December 15, 1910

SPLASHES.

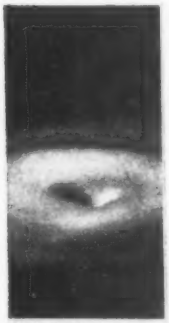
[EDITOR'S NOTE: This article was published in the February, 1911, *Outlook*, from which magazine it is taken for publication here. It was thought that it would have considerable interest in connection with the article by Walter Goodacre on Lunar Surface Formations, published in the April number (page 215) of this magazine, and also in connection with the article by Professor See published in this number, bearing upon the impact and capture theory].

The pictures shown on the two pages following illustrate a curious and interesting "Study of Splashes" described by a former Professor of Physics in the famous Royal Naval College at Greenwich in a lecture before children. The lecturer, Mr. Arthur M. Worthington, asked and then answered the question: "When a bubble is formed, what becomes of the ascending central column previously seen?" The answer is shown in these


(1) DROP OF WATER FALLING INTO MILK
(2) DROP DISAPPEARING
(3) CORONET EFFECT PRODUCED
(4) CORONET RISING HIGHER
(5) CORONET SUBSIDING
(6) CORONET FALLING BACK
(7) CORONET SMOOTHING OUT
(8) CENTER CONE FORMING
(9) CONE RISING HIGHER
(10) CONE BECOMING A PILLAR
(11) PILLAR AT HIGHEST POINT
(12) PILLAR BEGINNING TO SUBSIDE

instantaneous photographs which we reproduce from the London "Sphere." The results differ according to the height from which the object which makes the splash is dropped. The special series of photographs here reproduced illustrate the splash of a drop of water, about a quarter of an inch in diameter, falling into about sixteen inches of milk mixed with water. "The object of adding milk to the water," said Mr. Worthington, "was to make the liquid light up better, and experiment showed that the character of the splash was not materially altered by the addition. The drop of water was electrically released from a cup, and then as it fell it became elongated. Striking the water, it threw up a little surrounding

(13) APEX OF PILLAR DISAPPEARING



(14) PILLAR VANISHES INTO THE MILK

crater of liquid, from whose edge at pretty regular intervals little jets shot up. This crater increased gradually in breadth and height, reaching its greatest elevation in an eighth or ninth thousandth of a second. The original liquid of the drop was swept up the sides of the crater, this being evidenced by the little streaks of black, which are particles of lamp-black brought down from the cup. For nearly a hundreth of a second the crater remained with little change of form; then it sank and widened when the rebound began. The bottom of the crater now began to rise in a column which gradually increased in height. This is the 'little crystal fountain' noticed in a shower of rain. Curiously enough, almost the whole of the original drop is collected at the top of this column. After reaching its full height the column then begins to subside, finally causing a well-defined outward-flowing ripple."

A great difference is seen in the splashes made by rough and smooth spheres and between those made by solid and hollow

spheres. Well-polished marbles were dropped into a deep glass bowl full of water, and the audience could see that they slipped in noiselessly with hardly any visible splash. The same spheres if wet, or roughened with sand paper, or even if dusty, made a great noisy bubbly splash accompanied by the projection into the air of a tall jet of water whose summit rose even higher than the place from which the marble fell. With the rough sphere the crater thrown up was curiously like that accompanying the splash of the liquid drop, and can be described as a "basket splash." The sphere in this case enters the liquid without really breaking the skin, which is drawn into a surprisingly deep cylindrical pocket containing air. This ultimately divides into two parts, the lower part constituting the bubble. With a smooth sphere, on the other hand, the splash is totally different from the very first instant of contact, for the liquid, instead of being driven laterally away, is retained by the force of adhesion and guided over the solid surface so as to envelop it in a liquid sheath of exquisite thinness.

THE TOP AND GRAVITATION.

HYLAND C. KIRK.

The man, who cannot look back with a feeling of pleasure to the days when he spun tops and watched with awe and delight their whirling, dizzy movements, will hardly be able to read this article with patience or satisfaction.

"How does it keep itself up—and get up again when it's down?" were the boyish questions; and the answer here given, to the latter at least, and which it is proposed to explain, is that gravity acts upon the top downward as a pressure affecting it as it does the common gyroscope to sustain and right it in the air.

That the top when spinning depends upon the same principles for its support as the gyroscope for its elevation in rotating on its axis and revolving around its supporting center is apparent when the two mechanisms are compared. The peg top has a greater degree of freedom in the fact that it is not enclosed in a frame and does not rotate on two pivots like the disk of the gyroscope; and because of this fact it shows more clearly

perhaps in certain of its phases the character of the force affecting it than does the former instrument.

A spinning top whose peg is free to turn in a cup or on a swivel at the upper part of the pedestal (Fig. 1) may be made

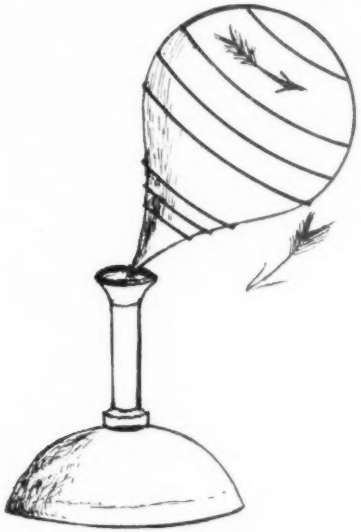


FIGURE 1.

to move and act very much like a rotating gyroscope revolving in a horizontal plane about its point of support (Fig. 2); while the ordinary gyroscope, when it rises and rotates by reason of the forces impelling it with its axis perpendicular to the socket in which it revolves, is seen to be very much like a top when *asleep* (Fig. 3).

One difference is that the top rolling on its peg moves around in the same direction in which its upper surface rotates, instead of the direction of its lower surface; though, if supported above its center of gravity, or if constructed so that its center of gravity is below its point of support, it precesses in the same direction relatively as the gyroscope revolves. And the common top often agrees with the action of the gyroscope in the fact that the faster it spins or rotates, the slower is its forward or circling movement; and this is likely to be the case unless considerable forward impetus is given the top when started on its spin. Valuable data in this connection are afforded by a close comparison of the two instruments.

Various of the early explanations of the gyroscope as those of Professor W. R. Johnson (1832), Professor Baden Powell and others, as well as some later ones, refer both its sup-

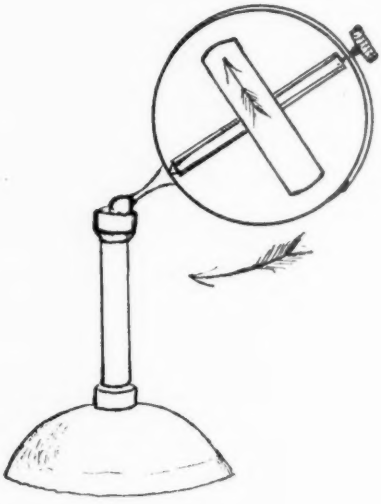


FIGURE 2.

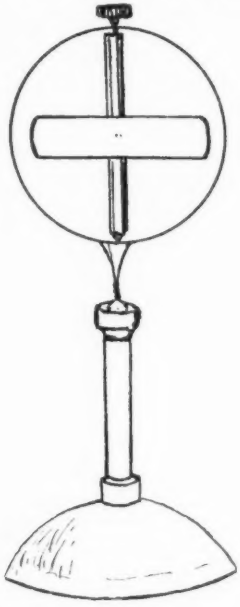


FIGURE 3.

porting power and direction of the disc's movement to the general laws of rotation as established by Frisi and others; and in such explanations it is pointed out that the centrifugal force of each particle of the upper moving half of the disc, when revolving horizontally, combined with gravity tends (Fig. 4) to make the upper half fall outwardly and the lower half inwardly, thus tending to impel the disc around the pedestal in the direction of the rotation at its base; while the resultant of its revolution about the pedestal with the centrifugal forces of the lateral halves of the disc sustains it in the air.

Not doubting the general correctness of Frisi's law, or that these resultant forces have an important effect in their reactions, the fact that the same reasoning, making use of the application of these forces alone, will not explain the rising of the top nor why the gyroscopic disc rises above the horizontal, makes it tolerably certain that the initial if not controlling cause of these movements lies in a peculiar force affecting the

disc above its center of gravity, which a close analysis confirms.

According to this early form of explanation, in the upper half of the disc (Fig. 4) each particle, as at A, may be regarded as acted upon by two forces, a centrifugal force AE, and the

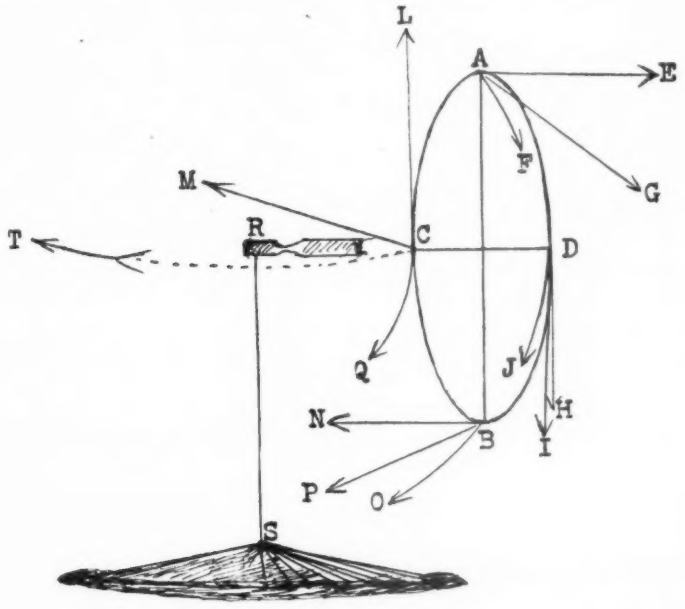


FIGURE 4.

force of gravity AF, between which it tends to take a direction outwardly and down, that of their diagonal AG; while in the lower half a particle as at B, acted on by a centrifugal force BN and gravity BO, must tend to take a direction inwardly and down, that of their diagonal BP. It is then assumed that the resulting torque between the forces of the upper and lower halves of the disc will tend to impel the disc around the pedestal RS in the direction T, the same as that of the movement at the bottom of the disc.

As stated in the previous article this could not be the case as the result of an attraction or pull of any sort at a point below the center of gravity in the disc, since the general tendency of this movement being downward, despite the sustaining forces thus far referred to, a new or precessional axis below would greatly increase the rotative energy on the upper side

which would tend to carry the disc forward in that direction, to swing it around this new axis and bring it speedily to the ground.

But in this explanation the direction of the revolution around the pedestal being assumed to be established, the disc is believed to be sustained as a resultant of this revolution CT and the centrifugal force of the two sides ACB and ADB, which, because the diagonal CM of the centrifugal force CL and the path of revolution CT tends upwards, is believed to sustain the disc in air.

The investigator who rests satisfied that he has here the true explanation of the movements of the gyroscope and top is more than likely to change his mind if he looks into the matter more carefully. The fact, that the diagonal AG (Fig. 4) between the centrifugal force and gravity in the upper half and the corresponding diagonal BP in the lower half, as well as DI of the side ADB, all tend downward, so that the resultant tendency of these forces in three-fourths of the disc must be downward, will not explain why the instrument frequently rises above the horizontal, but on the contrary demands that some other force must be operative to effect such a result.

It is true that the difference in direction of these diagonals, CM and DI of the two sides, tends to create a torque in the vertical line AB of the disc; and while on this account no reason can be found why a new axis should be centered in this median line, as shown in the previous article on "The Truth About the Gyroscope",* there is an excellent reason for such location when the relative motion of the two sides of the disc are taken into account—a conclusion which the activities of the top supplement and enforce.

A top spinning at an angle (Fig. 5) is subject to the action of centrifugal force and gravity the same as the gyroscope; and a glance shows that these forces as ordinarily recognized could not possibly sustain or right the top when thus rotating. For not having a separate revolution like the gyroscope, it is the more easily seen that, the resultant diagonals CI, FO, and DR, all tending downward, and the fourth diagonal EL alone the resultant of the upward action of centrifugal force and the downward action of gravity, it is inconceivable that the top should be sustained and even regain its equilibrium thereby; so the real reason must be assigned to another cause.

* See page 200.

If a top weighs four ounces, it is clear that, in spinning at any angle from the vertical, two ounces are constantly lagging back on the side CED of the plane CDA, passing through the top (Fig. 5). and that the same weight is constantly acting downward and tending to increase the motion on the opposite side CFD. To deny that the particles on the two sides have such natural impulses is to deny that the particles may

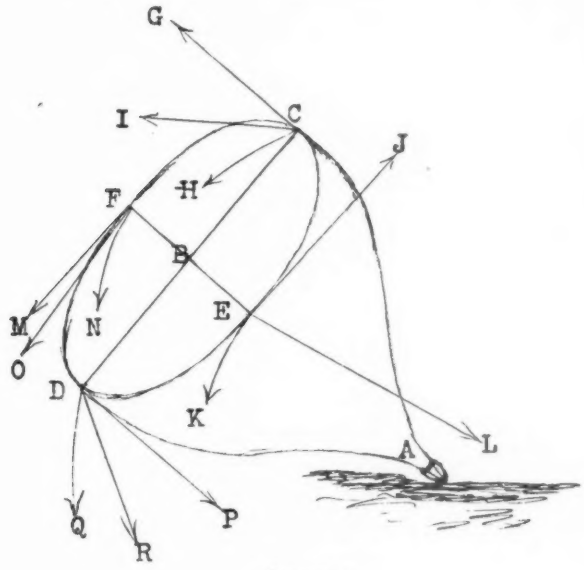


FIGURE 5.

be affected by centrifugal force or any other force. In the plane DCA, neutral to the rotation and separating the rising and descending particles, a precessional axis will necessarily form tending to give the top a new movement.

But why, it may be asked, will such a neutral plane of demarcation be formed between the rising particles of the gyroscopic disc, rotating vertically and of the top when spinning at an angle from the perpendicular, and of the descending particles? The answer is for the same reason that a stone or ball stops when it is thrown upward into the air, the retarding weight of each particle has its effect and the height it reaches is a point of rest through which gravity effects each particle in that plane of the disc without reference to the retarding effects of the rising, or accelerative effects of the descending

particles; and in this plane a precessional axis must be formed above the center of gravity, dependent upon the relative position of that center and the inclination of the disc or top.

According to the established law, if gravity were an attraction, its greatest effect in this plane would be nearest the Earth and below the center of gravity in the top, the effect of which would be to increase the rotation on the opposite or upper side and bring it speedily to the Earth. The action of the top, in rising on its pivot, makes it positively certain that the precessional axis formed in this neutral plane is located above the center of gravity and exerts a downward pressure upon it in order to cause a greater force of rotation on the lower side and bring it to a balanced, erect position.

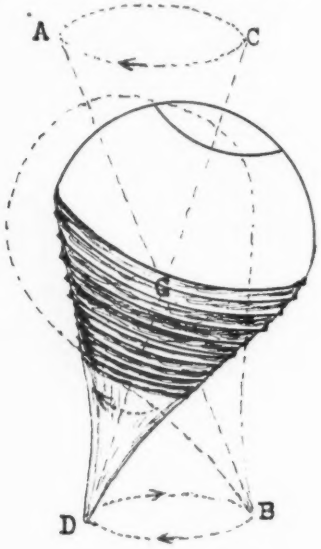


FIGURE 6.

It is well established that an ordinary spinning top which appears to rotate about its axis of figure (CD, Fig. 6), while also executing a conical movement DGB about the vertical, is constantly subject to another rotation about an instantaneous or precessional axis extending through its center of gravity and coinciding neither with the axis of figure nor with the vertical—and the formation of this axis is a chief cause inducing its precession, or what may amount to a retardation of the forward movement of the top on its peg. Accordingly it must be

the forces producing this axis and acting through the center of gravity with the point or peg as a fulcrum which rights the top when it careens by increasing the rotation on the lower side.

Though it may appear to be a strange statement, while the gyroscope has been explained approximately many times and by many individuals as a result of the application of Frisi's law, the balancing of a top when it rises without a forward movement increasing the force upon the peg, as sometimes happens, has never been explained, except on the assumption that the force driving on the peg at the point where it happens to be stayed in its course reacts to "hurry on the precession", or to create a new axis for righting the top.

Euler in his "Theoria Motus Corporum Solidorum seu Rigidorum," (1768), and Whewell in a later treatise (1833), attributed the rising of the top to friction of the peg combined with centrifugal force, which is only true so far as it goes but clearly inadequate for some cases, because the centrifugal force is equal on all sides, and when the top is attaining equilibrium with the peg relatively stationary, its friction affords no cause sufficient why the rotation should be increased more on one side than another to bring about such equilibrium.

Professor John Perry in "Spinning Tops" (1901), and Harold Crabtree M. A., in the latest work "Theory of Spinning Tops" (1909), both explain the rising of the top in the simple language given by Lord Kelvin: "Hurry on the precession, and the body rises in opposition to gravity", which is practically the same explanation as that of Euler and Whewell.

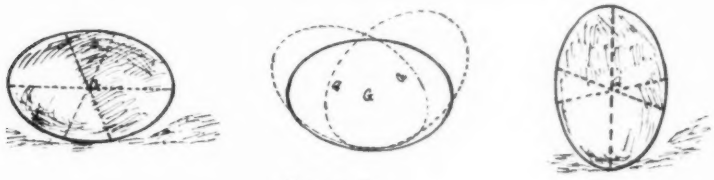


FIGURE 7.

While it is true that a top will not spin on a surface so smooth that it affords no opportunity for the peg to gain a "foothold", it is also true that the peg may operate on a surface where there is no more apparent opportunity for reaction to occur on one side than another, in which case the axis of precession must certainly be caused by some force other than the reaction from the peg. This is enforced by the fact that if you set whirling a hard boiled egg or a smooth oblong pebble

(Fig. 7) with sufficient vigor it will rise and spin on its longest axis, the initial force apparently being in the egg or pebble itself, and not due to any peg or outside obstruction. Says John Perry: "You will find that nearly any rounded stone when spun will get up in this way upon its longest axis, if the spin is only vigorous enough"; and this happens we say because the pressure in the vertical plane above the center of gravity, G (Fig. 7), in the stone elevates it a little higher at each wabble, until it rotates about its longest axis as the position of least resistance or greatest freedom of movement.

Gravitation as a force is not usually recognized as correlated with molecular forces, but only as applying to masses, however great or minute they may happen to be, and as uniting with forces which produce motion in masses of matter. Yet there is no escape from gravitation or its influence and when combined with other forces, as in the case of a rotating body, its action ought to be clearly distinguishable. A plane neutral to the action of a pound, an ounce, or the slightest fraction of a grain, rising on one side of it and falling on the other side, must when free to do so, show its peculiar neutrality to these rotative forces, and have an effect upon the body manifesting it; and this is clearly the case in the top, because it explains what cannot be explained in any other way.

When the top is rotating at a perfect balance this precessional axis does not of course exist, the downward pressure merely tending to preserve its equilibrium. The action of gravity as a pressure upon a terrestrial body perfectly dense and impenetrable could be exerted only upon its outer and upper surface; but as all material bodies are more or less porous, the measure of gravity, which as an attraction we are accustomed to regard as being exerted in the plane of an ordinary body's base, must in proportion only as it is dense and impenetrable be exerted upon its upper surface. Gravity must also be modified in any given body by the shape and movements of that body, irrespective of its density. Inverted cones and pyramids resting on their pinnacles must have, as a whole, a greater pressure on the broad upper and exposed surface than on the smaller plane areas below, the aggregate being determined by the effects upon the center of gravity; hence gyrating discs and cones can only display precessional effects of this pressure when rotating with their axes divergent more or less from the vertical. Hence the common gyroscopic disc always has such a precessional axis, unless it takes the

attitude of a top asleep, while in the case of the top, gravity simply stands guard to right it when it careens.

This downward pressure acting through the center of gravity must have a staying influence upon all bodies in motion, and it is not impossible that an instinctive relation exists between it and living creatures in flight and locomotion. Attempt to drop a cat on its back and it at once shifts its center of gravity, curling its tail inwardly and drawing its left feet close to the body, its right feet are shot vigorously into the air, the fore-paw thrown across the body, and the cat, before you have time to utter a syllable, strikes on its feet.

That man has not such an acute sense of gravity is illustrated by Professor Rankine in his "Mathematician in Love":

> "The lady loved dancing;—he therefore applied
> To the polka and waltz, an equation;
> But when to rotate on his axis he tried,
> His center of gravity swayed to one side
> And he fell by the Earth's gravitation."

There is no escape from the influence of gravitation and the riddle of its relation to other forces has been very elusive and discomfiting. In the preceding and present article, it is pointed out that the gyroscope, in its common form, and the top, both suggest the true character of this force; and this view will be still further upheld by a consideration of "The Gyroscope as a Compass", resting upon scientific data already accepted and a statement of which can aggrieve no one by militating against opinions already formed, as may be the case with the elucidation of these commoner rotative toys.

AN HYPOTHESIS OF THE ORIGIN OF ANTI-CYCLONES.

W. F. CAROTHERS.

The following meteorological observations may be of interest to readers of POPULAR ASTRONOMY, especially because of their probable bearing upon the very live and important question of solar radiation. What follows is necessarily very much condensed because a full account of my work on this line would occupy too much space in this publication.

From observations of three years of past weather maps, supplemented by various fragmentary records and now con-

firmed by more than one year of current maps, I have found that the anti-cyclones of the United States run in series, from three to eight at a time, each observing a law of periodical recurrence of twenty-five days—measuring from the dates of first full development at the successive recurrences. The life of a series ranges from three or four months to a year or more. Of 93 "highs"* appearing on the United States weather maps since February 7, 1910, when this discovery was made, twelve have missed their due dates as much as two days while the remaining 81 have come within twenty-four hours of the periodic days called for by this law. Not one has appeared outside of one or the other of the current series.

I find further that, as between related pairs of "highs" and "lows", the "highs" are the dominant force. This latter conclusion was reached more than a year in advance of the first mentioned and materially aided in reaching the more important result. This conclusion is substantially confirmed by Mr. Moore of the Weather Bureau in his new book on meteorology published in April, 1910.

My hypothesis is that areas on the Sun, acting as if relatively hot and having a synodic rotation period of twenty-five days, cause extra upheavals or expansions of the atmosphere at our heat equator eventuating in downpours of cold air from higher altitudes in our northern latitudes which we know as anti-cylones; that these downpours draw up strong currents of air over their sides producing the cyclones. Subject to solar and terrestrial changes and also apparently disturbed by causes not yet surmised, these effects succeed each other with each revolution of the Sun and hence the serial character of the movements.

The evidences supporting this hypothesis as an explanation of the observed phenomena may be summarized as follows:

1. The hypothesis is in harmony with the general laws of atmospheric circulation. The ordinary heat of the Sun raises steady currents of air at the heat equator the year round and these drift towards polar regions descending in latitudes of forty to fifty degrees north and south respectively. An extra hot area on the Sun might be expected to produce the special effects described.

2. The anti-cyclones themselves have a well known *downward* tendency which even contributes to their high barometric pressure. The hypothesis calls for just such a downward tendency.

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* Note: I have used the terms "highs" and "lows" in many places in this article as handy substitutes for the technical terms anti-cyclones and cyclones. As a matter of fact the observations relate only to definite anti-cyclones and cylones. W. F. C.

3. Anti-cyclones have favorite places to "form"—i. e. over cold regions. A body of air in high altitudes seeking to come down would tend, by the action of gravity, to descend in paths, not above warmer regions where the pressure from below might be great, but above cold regions where the natural tendencies are already downward.

4. The anti-cyclones are *dry* where they descend to the surface ("form" as has been commonly supposed). Now if they actually formed in those northern regions we ought to find precipitation there for the reason that where air is originally chilled its moisture is condensed. The fact that the highs are *dry* when they first come within the range of surface observation is evidence that they have come from elsewhere, and the further fact that we have the necessary precipitation at the heat equator to account for their origin there would seem to point to that region as their real birth-place.

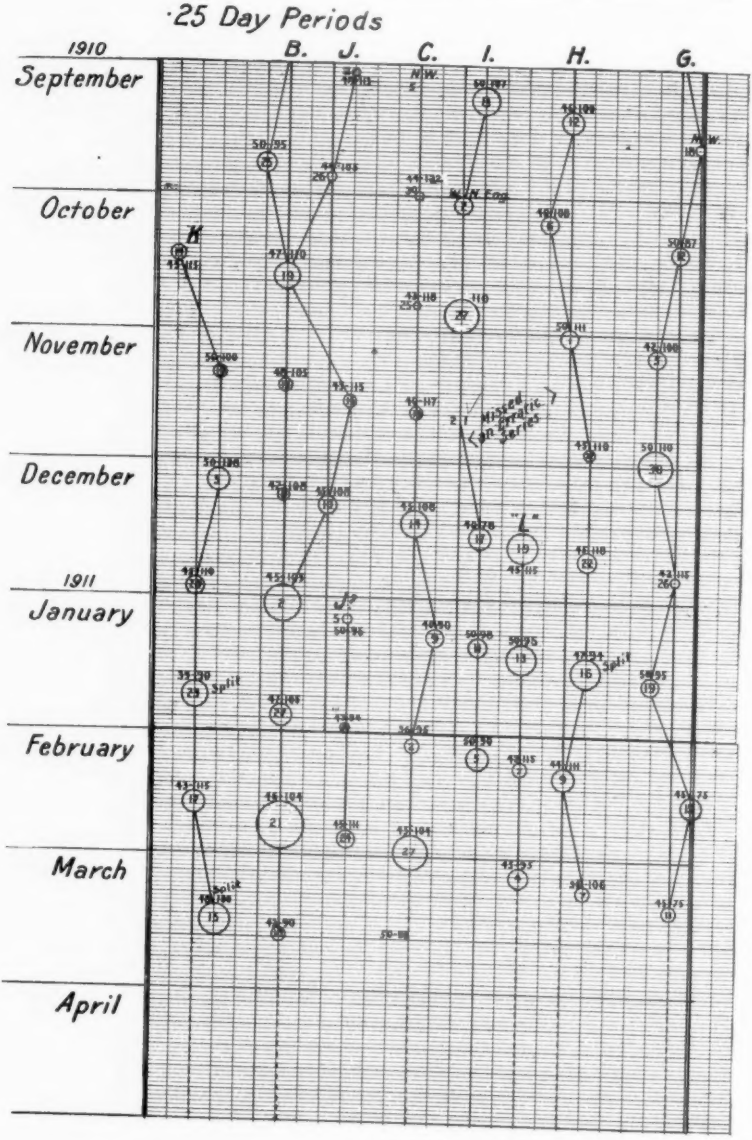
5. The "highs" are intensely more *cold* where they have seemed to "form" than large sections much farther north. We here suppose them to have acquired their abnormally low temperatures from the high altitudes into which they are forced at the heat equator. No other explanation of this phenomenon has been advanced which has satisfied meteorologists, but Mr. Moore's new book advocates the altitude explanation of the temperatures of the anti-cyclones other considerations such as radiation etc., being also taken into account.

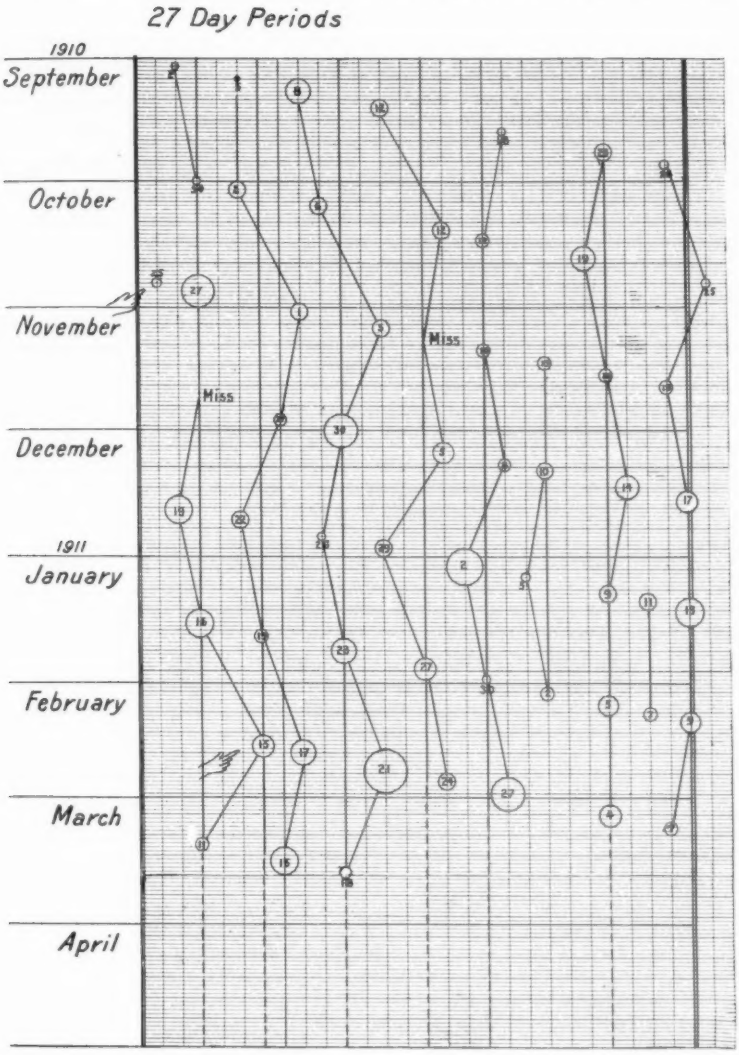
6. The duration and varying numbers of the discovered series of "highs" bear a striking analogy to the well known laws of change on the Sun itself. In fact it was a study of these solar changes as presented by my graphic solar discs described in POPULAR ASTRONOMY for June, 1910 that led to a search for just what was found—except that we started out to look for a twenty-seven day serial periodicity instead of a twenty-five day as found.

7. The fact which we have carefully tested, that the summer's heat does not *disarrange* the periods, even though largely overcoming the "highs" in that season, indicates that the *cause* of the series and periods is extra-terrestrial. Were they of terrestrial origin we might expect to see them disarranged in the summer, to start up in the autumn on entirely new dates.

8. The observed phenomena of series, the regular periods therein, is just what would be produced by a neighboring globe with causative points upon it revolving with a synodic period of twenty-five days.

I have included in this report a chart of the "highs" for the winter just closing, which is a fair sample of what the weather maps reveal. Each series is designated by a letter of the alphabet and the successive appearances of the "highs" are shown by the circles, the size of which I use to indicate the barometric pressure at the center of the high on the day of its full development, each one of the fine horizontal lines embraced in the diameter of a circle indicating one-tenth of an inch pressure above thirty. Figures embraced in the circles give the date of the development and a double set of figures above give respectively the latitude and the longitude of the center of the "high". All data have been taken from the Washington weather maps kindly sent me by the Weather Bureau and


·25 Day Periods
1910
September
October
November
December
1911
January
February
March
April
B.
J.
C.
I.
H.
G.
K
"L"


27 Day Periods
1910
September
October
November
December
1911
January
February
March
April
Miss
Miss

I have been greatly assisted on close points by the wider range of field of the Canadian weather maps for which I am indebted to Mr. Stupart, Director of the Canadian Meteorological Service.

This method graphically illustrates the vital points in this study. Of course I have been careful not to confuse the different "highs" shown on the maps, each one of which occupies the stage from three or four to eight or ten days, there being often two "highs" on the map at once. I have counted each "high" but once, that being on the day of its first full development. Neither have any regularly formed "highs" been omitted. It will be seen that this method fixes the actual chronological relations of the respective "highs" mechanically and according to a true scale, or scales I should say, since the scale from top to bottom is much condensed in comparison to that from left to right—one line in each case representing one day.

Mr. C. G. Abbott of the Smithsonian Institution suggested that other periods might make a similar showing and that I try a forty day period. Professor W. J. Humphreys of the Weather Bureau made a similar suggestion and that solar rotation ought to produce a twenty-seven day periodicity, if any at all. I had also read of claims of six and seven day periods (as applied to the cyclones, however, the current theory being that they are the dominant force). Therefore I carefully platted the dates of the highs for about one year on similar charts scaled to periods of eighteen days (which would also show a periodicity of six days if it existed), twenty-one days (which would embrace a possible seven day periodicity), twenty-six, twenty-seven and forty days. The result in each case was that no semblance of permanent serial order could possibly be constructed on any of them. Some of them can be made to start off with the appearance of order but they invariably go all to pieces in a few months. The twenty-seven day chart is printed here with the twenty-five day chart so that a comparison of the two may be made. The series on the twenty-seven day chart are manifestly artificial, while it is impossible to do even that much with the others. In view of the fact that the twenty-five day periods have held unfailingly for nearly four years of continuous record the breaking down of these other periods I regard as strong negative evidence in favor of the results claimed for the former.

Many minor lines of confirmation have appeared in the past year. There is much positive evidence of serial character in

the "highs" themselves, such, for instance, as the repeated weakness of Number "C" at its successive developments of September 5, 30, October 25 and November 19 paralleling the strong Number "I". These points are too numerous to detail here.

Chief among the confirmatory evidence have been the results of actual forecasting tests. Space forbids a full account of these but I will mention some of the more pronounced. As a locally public test of the proposition I conducted a long range forecasting of the "highs" due to develop in the United States for a period of fifty days, from September 1 to October 22, 1910, in the "Houston Chronicle" which also publishes the weather maps. At the close a committee appointed by the paper found that, of ten "highs" forecast, six developed on the day set, three within twenty-four hours and the tenth one within forty-eight hours—the latter referring to Number "J" which I forecast for October 21, but alternatively stated in the Chronicle of October 1 that it might unite with Number "B", a thing that actually happened on October 19. Closing the test on October 22 I referred to Number "B" as follows: "A norther is due to reach Houston Tuesday of carnival week (November 14) and should afford several days of bracing weather for that occasion." Number "B" reached Houston at 9 P. M. on the evening set.

On the first day of December, 1910, I gave both local papers a forecast for the first twenty-five days of the month. We were then in the midst of a prolonged drouth. I said: "There are two chances for rain in this period the first being a wet norther from the tenth to the thirteenth (based upon the anticipated actions of "B" and "J" which have manifestly been related) and a regular rain period on the twentieth and twenty-first (based upon the serial character of the "low" preceding Number "H")." The wet norther reached Houston November 12 and lasted several days, partially breaking the drouth and the low of number "H" brought us a 2.28-inch rain on December 22, effectually breaking the drouth, no other rains occurring here in the meantime. Thus I was able to forecast, not only the approximate dates of local rains, but their character, the one from a norther and the other from a "low." I have been careful always to make it known that the forecasts were but tests or experiments, and I do not now mean to convey the idea that the problems connected with reliable long range forecasting are all solved, certain variations of intensity, path etc., yet remain to be mastered before the result is achieved.

If my hypothesis is the correct explanation of the observed

behavior of these dominating weather movements it ought to give definite point to the investigation of variations in solar radiation. The series of "highs" would then, in each case, reveal the relative solar longitude, the rotation period and the number of the suspected areas. While the Sun is the principal study at my little observatory my equipment limits me to visual work. From private correspondence with men who are masters in this field it seems that there is now no evidence of the existence of such solar areas as the hypothesis calls for, but of course the subject is being investigated as never before and there is room to hope that they may yet be found and that speedily.* This done, so that the intensity of the coming movements may be measured and with the influences which retard or accelerate them and alter their paths ascertained, long range weather forcasting will have been placed on a reliable footing.

Houston, Texas, March 23, 1911.

PLANET NOTES FOR JUNE, 1911.

Mercury will reach its greatest elongation west of the Sun on June 1. It will then be about 24° or approximately an hour and a half in time west of the Sun. It may possibly be visible at this time in the morning just before sunrise. However, it will not rise at this latitude quite as long before the Sun as would be expected from the fact that it is an hour and a half west of the Sun, because it reaches its greatest heliocentric latitude south on June 5 and will consequently rise later than if it were farther north. On the first of June, Mercury will be about ten degrees west and ten degrees south of the Pleiades and will move eastward through Taurus and into Gemini during the month. It will pass its ascending node on June 24, and will be at perihelion on June 29.

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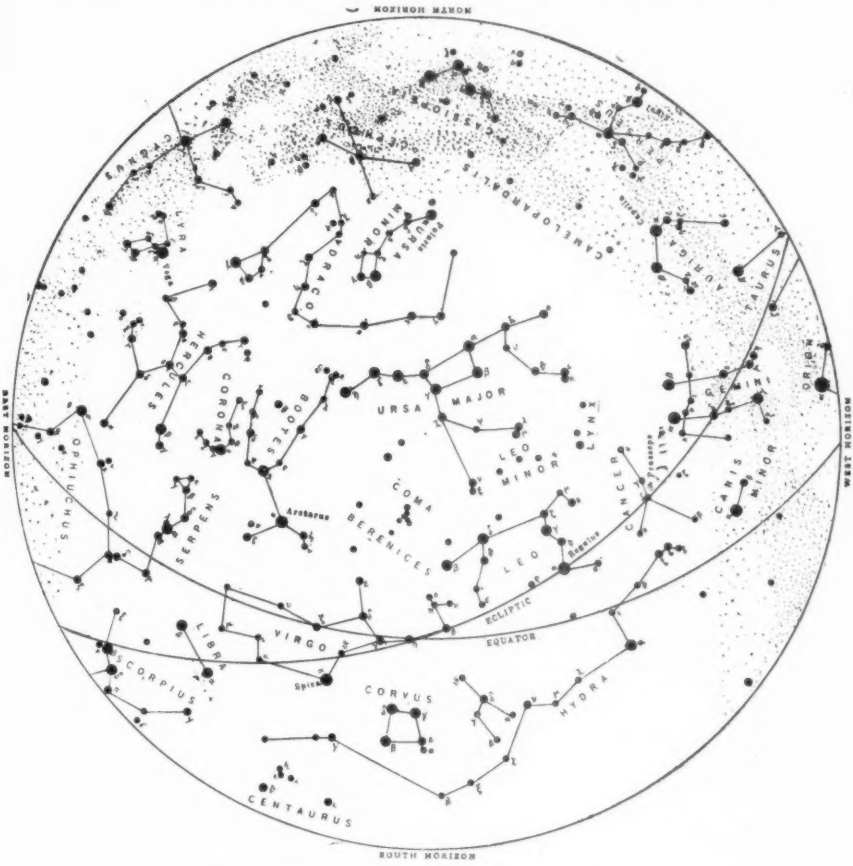
* After the above had already been set up the following statement from the director of the Astrophysical Observatory relative to this question, came to our notice. "The supposed variability of the Sun cannot be regarded as proved, unless affirmative results should be obtained in the proposed series of simultaneous observations at Mt. Wilson and in Mexico. If, however, we admit that a variability of the Sun is sufficiently shown for purposes of discussion by our Mt. Wilson work of the past years, such variability appears to be of irregular but very short average perod, running a cycle from low to high and back to low within five to ten days. The average would perhaps be seven days. You will find in the forthcoming number of the *Astrophysical Journal* information on this point. I would prefer that you should draw your own conclusions from this information, for I am not ready myself to advance an hypothesis of the cause of solar variability."

Venus will continue during this month to be the evening star which will be conspicuous because of its great brilliancy. It will set about three hours after the Sun. It will be in conjunction with the Moon on June 28. It would be interesting during this month to try to see this planet in the day time. It can be done if one has some means of determining its exact position. It will



THECONSTELLATIONS AT 9:00 P. M., MAY 1, 1911.

be approaching the Earth during the month and its disc will become larger rapidly, its semi-diameter on June 15 being 9″.72 It will move from the constellation Gemini eastward into Leo during the month, and by the end of the month will be about five degrees west of Regulus, α Leonis, which is a star of almost the first magnitude.

Mars will be at its greatest heliocentric latitude south on June 6, and will be at perihelion on June 29. It will be a morning star during the month and will be quite high in the eastern sky at sunrise. It will be about 115 million

miles from the Earth by the middle of June and is approaching so that it is constantly becoming brighter. It will move eastward into the constellation Pisces during the month and will not be near any bright star.

Jupiter will be the most interesting object in the sky during this month in the early evening. It will rise in the afternoon and will be well up in the sky and favorably situated for observations at sunset. It will be very brilliant, though it will be rather far south, being 12° south of the equator. It will be found in the constellation Libra.

Saturn will reappear in the morning before sunrise in this month. It will be about 20° west and 10° south of the Pleiades. It will move eastward slowly in Aries.

Uranus will cross the meridian quite low in the south before sunrise. It will be found in the constellation Sagittarius.

Neptune will get very close to the Sun during this month. It continues to move slowly in the constellation Gemini, about 15° north of Procyon, a 0.5 magnitude star.

Venus Observed at Noon.—Because of the predicted occultation of the planet Venus by the Moon which was announced to take place about noon, Washington Mean Time, on April 1, the writer attempted on Monday, March 27, to see Venus with the naked eye before sunset. The position was found by using the telescope at Goodsell Observatory and then the planet was easily observed with the naked eye about an hour before sunset. It was easily visible from a position in the dome where the eyes were protected from the glare of the Sun, but even on going outside it was still quite easily visible. On the day of the occultation, which appeared as at this latitude as a close conjunction merely Venus was again seen with the naked eye. This time both the small crescent of the Moon and Venus could be seen without difficulty at the time of the conjunction, though the Sun at that time was very bright, being approximately on the meridian in a very clear sky. An entire class of thirty-five observed the phenomenon from a position in the dome where the Sun could not strike the eyes. These people of course were unaccustomed to observational work, hence the fact that they could see it is evidence that the planet was quite bright. I went outside then and saw it even in the bright sunlight outside. I followed the planet for about two hours with instruments and also with the naked eye, being able to see it easily at the time of its transit across the meridian.

Carleton College. C. H. G.

Directions for finding Neptune.—No amateur should fail to take this favorable location of Neptune as an opportunity of finding it. Not many amateurs have viewed Neptune. To the left of Delta Geminorum is a small sickle of quite bright stars that can easily be seen with a pair of operas. Neptune makes sort of a handle for this and is but a few minutes of arc away. I have an article in the *Scientific American* for April 1 which gives an accurate map and location of Neptune on April 1. Because of its very slight motion during April it should be very close to this indicated position by the time this article reaches the readers of POPULAR ASTRONOMY. Though this map was

constructed last fall an observation of Neptune since it was published verifies its correctness. No one need have any trouble locating Neptune with even a pair of good opera glasses. I have not been able to clearly distinguish Neptune's beautiful green color in any aperture less than my 16″ reflector. It presents a fine disk of good size in this fine instrument. I had considerable confidence the other night that I saw Neptune's Moon in the 16″ but am not absolutely certain. It was suitably elongated at the time but I have never learned in how small an instrument this satellite has been seen.

Further attention should be called to the fact that on April 28 Juno is very close to Delta Virginis and on May 1 or early May 2 Vesta will be very close to Epsilon Tauri. The ephemerides are given in the *Scientific American* of April 1 as referred to above.

RUEL W. ROBERTS.

Edgerton, Wis.

Occultations visible at Washington.

Date 1911	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	IMMERSION. Angle f'm N. °	EMERSION. Washington M.T. h m	EMERSION. Angle f'm N °	Duration h m
June 2	42 Leonis	6.1	8 16	78	9 2	350	0 46
11	163 G. Ophiuchi*	6.3	15 58	108	17 5	244	1 7
13	234 B Sagittarii	5.9	11 36	134	12 39	222	1 2
16	161 B Capricorni	6.4	14 46	353	15 17	311	0 31
29	107 B Leonis*	6.3	10 14	153	10 52	256	0 39

* Emersion below the horizon of Washington.

Phenomena of Jupiter's Satellites.

Central Standard Time.

1911	h	m				h	m			
June 5	11	38	I	Oc.	Dis.	12	18	III	Tr.	In.
	12	7	II	Oc.	Dis.	15 7	19	I	Tr.	Eg.
6	8	53	I	Tr.	In.	8	17	I	Sh.	Eg.
	9	41	I	Sh.	In.	16 8	15	II	Ec.	Re.
	11	4	I	Tr.	Eg.	18 7	36	III	Ec.	Re.
	11	53	I	Sh.	Eg.	21 9	40	I	Oc.	Dis.
7	8	15	II	Sh.	In.		11	21	II	Tr.	In.
	8	50	III	Tr.	In.	22 8	0	I	Sh.	In.
	9	3	I	Ec.	Re.	9	8	I	Tr.	Eg.
	9	13	II	Tr.	Eg.	10	12	I	Sh.	Eg.
	10	17	III	Tr.	Eg.	23 7	21	I	Ec.	Re.
	10	52	II	Sh.	Eg.	10	52	II	Ec.	Re.
	12	6	III	Sh.	In.	25 7	21	III	Oc.	Re.
13	10	40	I	Tr.	In.	10	16	III	Ec.	Dis.
	11	36	I	Sh.	In.	11	35	III	Ec.	Re.
	12	52	I	Tr.	Eg.	28 11	30	I	Oc.	Dis.
14	7	52	I	Oc.	Dis.	29 8	47	I	Tr.	In.
	8	59	II	Tr.	In.	9	55	I	Sh.	In.
	10	50	II	Sh.	In.	10	59	I	Tr.	Eg.
	10	58	I	Ec.	Re.	30 8	35	II	Oc.	Dis.
	11	34	II	Tr.	Eg.	9	15	I	Ec.	Re.

Note.—In., denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of the satellite; Sh., transit of the shadow.

COMET NOTES.

Concerning the Physical Constitution of Comets.—In the *Astronomische Nachrichten*, No. 4468, is found a discussion on the physical constitution of comets based largely upon the phenomena presented by Halley's comet. The article was written by D. Eginitis, Director of the Observatory at Athens. The following excerpts are made from his article.

Halley's comet, during its last apparition, presented variations of brilliancy which are of special interest for their valuable indications relative to the physical constitution of these bodies.

The tail, particularly from May 9 until the morning of May 21, became paler and paler while approaching the Earth instead of increasing in brilliancy; the last nights before the conjunction it appeared to us dark, almost black, as though it were composed of smoke. While the tail was already very faint on May 10, we noticed on May 17 that it was much paler than on the preceding nights. Mr. W. W. Campbell telegraphed that on the morning of May 19 the brightness of the tail was but the third of that of the preceding evening (*A.N.* 4414). Dr. Max Wolf said that the tail had always been pale; the most distant parts, toward the end, were on May 17 scarcely half as bright as the Milky Way in Aquila; May 15 the light of the tail was so pale that the details were observable only with difficulty (*A. N.* 4416). Hartmann assigns to the tail on May 18, the same brightness as the Milky Way in the palest parts (*A.N.* 4414). But this diminution suddenly stopped after the passage of the tail to the other side of the Earth. The portion of the tail observed the evening of May 21 in the west, when it was moving away from the Sun and from the Earth, suddenly took on a startling luminous intensity. It no longer had that somber, smoky aspect so unusual; it took on a light color, almost whitish or slightly gray. That evening it was easily seen by the naked eye, before the end of the twilight in spite of the strong light of the Moon (12 days old), through a light bank of clouds; while in the morning it was not visible in the east until the complete disappearance of the moonlight, and it quickly faded away, effaced by the first rays of the dawn. Moreover, it is in consequence of its great paleness that one could not discover anywhere with the naked eye that evening, and at the same time with the other branch, the one that was observed again the next morning in the east. Evidently it is not a question here of an increase of brilliancy corresponding to one or two magnitudes, which would be quite natural considering the great difference of the angle at which we have have successively seen this portion of the tail first on one side of the Earth and then on the other; but rather of a sudden transition which could not be less than five magnitudes. The brilliancy of the tail began again to diminish very rapidly in the evening after May 21, conformably to the usual law, since it was moving away from the Sun and the Earth.

An analogous phenomenon, but in a much smaller degree, was presented by the head also; after having increased considerably in brilliancy while approaching the Sun up to the beginning of April, it then remained almost invariable at about the second magnitude during nearly a month before the inferior conjunction; increased again May 21 to more than the first magnitude and gradually diminished afterward. Thus from a magnitude of 9.5 observed March 7 it gradually increased to a magnitude of 2—2.5 April 17 (Giacobini,

C. R. p. 955). On May 15 we found it of second magnitude. The evening of May 21 it increased to above first magnitude (*C.R.* p. 1494); after that it constantly diminished.

According to the theory the size of the head ought to have increased constantly in order to reach the value 1 by May 15, and the value of 1.7 by May 21; following the reckoning of M. Giacobini it would be from 1.3 to 1.8 about May 19 (*C. R.* p. 955). The difference then between the theory and the observation would be about three degrees on May 15 and two degrees May 21; the theory then would indicate about May 15 a brilliancy of the head about 16 times as great as that which was observed.

M. Nordmann has also found for the nucleus that "between Apr. 25 and May 23 its brilliancy increased by a much smaller quantity than the usual theory indicated" (*C. R.* p. 1733). These are the facts proved; it now remains to seek their cause. And first, that sudden and striking increase of brilliancy in a portion of the tail observed on the evening of May 21, supposing it to be after its passage to the other side of the Earth, ought not to be attributed, at least in great part, to anything but the reflection of the sun-light; for, after this passage it was the side directly illumined by the Sun which was turned toward us, while we saw the opposite side before. The simultaneousness of these two facts could not be by chance.

It is in this way too that we may explain the constancy of the brightness of the head during nearly a month, contrary to the usual law; this constancy would then be due to the gradual increasing of its phase as it was approaching the Earth, supposing for instance the continual diminution of that part of the surface of the head directly lighted by the Sun and turned toward the Earth. It follows then that:

1.) The materials of which the comets are composed are but very slightly luminous; they can scarcely be seen but by the sunlight which they reflect.

2.) In the calculation of the brilliancy of the head one should consider, with the distance of the body from the Earth and from the Sun, its phase likewise. And yet we ought not to forget that there is an important objection made to the hypothesis of a very visible reflection of the sun-light on the tail of comets. The fact that the spectrum of tails observed up to this time was principally composed of bands, while the continuous spectrum, on the contrary, appeared sometimes faint and clearly crossed by the black lines of Fraunhofer (Huggins 1881 b), sometimes without these lines (Huggins 1882) and generally very faint, is worthy of close attention. But we must also take into consideration that the spectrum due to the solar reflection is continuous and consequently it ought to appear much paler than the other, which is not only formed of bands, but besides is doubled by the light of the parts corresponding of the continuous spectrum. As to the absence of Fraunhofer lines, observed sometimes, it is easily explained by the faintness of the spectrum, just as in the case of the zodiacal light.

In another point of view, the polariscopic observations seem to confirm the hypothesis of the reflection; as is known, many observers have found that the caudal light is partially and strongly polarized. And this polarization would be very difficult to explain without this hypothesis. Besides, the photometric measures of Mr. Nordmann tend also to prove that "the light of the nucleus is almost exclusively, if not entirely, sunlight" (*C. R.* p. 1734).

But what must be the physical constitution of the comet in order that the increase of its brilliancy, observed May 21, should be so great? It is evident that

the greater this difference is, the more improbable is the hypothesis of a constitution purely gaseous. The hypothesis that is thus confirmed is rather that of a mass composed of gas and containing solid corpuscles for the tail, or solid bodies of some unknown substance for the head. This result, which tallies well with the observations, agrees also with the theory of cometary origin and with the accepted ideas about the physical constitution of the mass of shooting stars. Moreover, this result conforms to the hypothesis of the production of cometary tails by the pressure exerted by the Sun's rays; this theory would, in fact, be inadmissible in the case of a purely gaseous constitution of comets.

VARIABLE STARS.

Two New Variables:—From the *A. N.* 4489, we get the following note. Mme. L. Ceraski has found two new variables; the approximate coördinates of the one of February 1 are:

10.1911 Lyncis

$\alpha =$	8^h	6^m	55^s	$\delta = +40°$	$34'$	(1855.0)
	8	9	57	$\delta \quad +40$	26	(1900.0)

There are twenty-three photographs of that region, taken between 1907 and 1911. A discussion of these plates leads M. Blazko to say that the light of this star varies from 10.5 to less than 12.5 magnitudes, and that the period is probably long.

The provisory elements are:

Max. = 1910, Mar. 6 + 310 E.

From this a maximum may be expected about the middle of November 1911.

The approximate coördinates of the star of February 8 are as follows:

11.1911 Persei.

$\alpha =$	3^h	10^m	57^s	$\delta = +32°$	$37'$	(1855.0)
	3	13	44	$= +33$	47	(1900.0).

Near the variable is found a star of about the twelfth magnitude (the angle of position of which is about 330° and whose distanceis 1′). Almost in the same direction at a distance of 2′ there is another star, a fainter one, of about 12.5 magnitude.

There are twenty-five plates of this region of the sky (1904-1911). A consideration of these plates leads M. Blazko to the conclusion that the light of this star varies from 10 to less than 12.5 magnitudes and that the period is probably long. The provisional elements are:

Max. = 1909, Jan. 1 + 338 E.

The maximum ought to take place about the middle of October 1911.

Colored Stars near Nova Lacertae.—In *A. N.* 4476 M. Luizet has called attention to the stars, B. D. 51°.3414 and 51°.3416.* From a comparison of his observations of February 15, 16, 20 and 21 with the B.D. magnitudes and with a photograph taken by Professor Wolf on January 10, 1911, he infers that B.D. 51°.3414 diminished in brightness by 1.5 magnitudes between January 4, and February 21.

During the early observations of *Nova Lacertae* made here the marked contrast in the color of these two stars was noted.

Two series of plates have been taken with the 24-inch reflector; one, using ordinary plates sensitive to the blue rays; the other, using plates sensitive to the yellow in connection with a visual color-filter. On the plates sensitive to the blue, the two stars appear very nearly equal, while on the plates sensitive to the yellow, taken in nearly every case only a few minutes later, there is a difference of nearly two magnitudes.

Spectrum plates taken by Mr. Parkhurst show that B.D. 51°.3415, which lies directly between 51°.3414 and 51°.3416, is a star of A type, and therefore may be used as a standard of reference. The comparison of the two smaller stars with this star shows that the difference in magnitude is due to color peculiarities in both stars. B.D. 51°.3416 appears nearly one magnitude brighter on the plates sensitive to the yellow than on the ordinary plates, indicating the predominance of the longer waves in its color, while B. D. 51°.3414 appears nearly one magnitude fainter on the yellow plates, showing that its color is due chiefly to the shorter waves.

If the B.D. magnitudes are correct, the star 51°.3414 must be variable, but photographs taken by Professor Barnard on October 11, 1893, August 7, 1907, August 22 and 24, 1909, and by the writer on January 3, 22, 23, 30, February 2, 4, 8, 9, 22, 23, 24, and March 2, of the present year give no indication of appreciable variation.

FREDERICK SLOCUM.

Yerkes Observatory, March 17, 1911.

[From a note sent to the *Astronomische Nachrichten.*]

Approximate Magnitudes of Variable Stars on Apr. 1, 1911.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn
χ Androm.	0	10.8	+46	27	<13	R Piscium	1	25.5	+ 2	22	7.6
T Androm.		17.2	+26	26	8.6 *i*	RU Androm.		32.8	+38	10	10.3 *i*
T Cassiop.		17.8	+55	14	8.8*d*	Y Androm.		33.7	+38	50	<13
R Androm.		18.8	+38	1	9.5*d*	Z Cephei	2	12.8	+81	13	<13.5
U Cassiop.		40.8	+47	43	8.2 *i*	RR Persei		21.7	+50	49	11.8 *i*
RV Cassiop.		47.1	+46	53	10.7*d*	RR Cephei		30.4	+80	42	13.5*d*
W Cassiop.		49.0	+58	1	10.0*d*	W Persei		43.2	+56	34	11.5*d*
S Cassiop.	1	12.4	+ 8	24	<10.4	U Arietis	3	5.5	+14	25	9.1*d*

* See page 249.

Approximate Magnitudes of Variable Stars on Apr. 1, 1911—Con.

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A 1900 h	m	Decl. 1900 °	′	Magn.
X Ceti		14.3	− 1	26	10.5*d*	W Leonis	10	48.4	+14	15	<11.7
Y Persei		20.9	+43	50	11.5*d*	S Leonis	11	5.7	+ 6	0	11.0*i*
R Persei		23.7	+35	20	9.0*d*	T Can. Ven.	12	25.2	+32	3	12.4*d*
W Tauri	4	22.2	+15	49	10.2*d*	T Urs. Maj.		31.8	+60	2	13.0*d*
T Camelop.		30.4	+65	57	9.0*d*	R Virginis		33.4	+ 7	32	7.6
RX Tauri		32.8	+ 8	9	9.8 *i*	RS Urs. Maj.		34.4	+59	2	<13
X Camelop.		32.6	+74	56	10.0*d*	S Urs. Maj.		39.6	+61	38	8.4*d*
R Orionis		53.6	+ 7	59	10.4	U Virginis		46.0	+ 6	6	9.2*d*
V Orionis	5	0.8	+ 3	58	14.0	S Bootis	14	19.5	+54	16	9.0 *i*
R Aurigae		9.2	+53	28	9.5 *i*	R Camelop.		25.1	+84	17	8.6
S Aurigae		20.5	+34	4	11.5*d*	R Bootis		32.8	+27	10	11.0
S Camelop.		30.2	+68	45	11.8*d*	R Coronae	15	44.4	+28	28	7.2
SU Tauri		43.2	+19	1	10.2	R Draconis	16	32.4	+66	58	13.0*d*
Z Tauri		46.7	+15	46	12.6 *i*	S Herculis		47.4	+15	7	8.6 *i*
Z Aurigae		53.6	+53	18	10.5	R Ophiuchi	17	2.0	−15	58	9.0 *i*
X Aurigae	6	4.4	+50	15	12.0*d*	RY Lyrae	18	41.2	+34	34	<14
SS Aurigae		5.8	+47	46	<13.5	V Lyrae	19	5.2	+29	30	10.8*d*
V Monoc.		17.2	− 2	9	12.2 *i*	S Lyrae		9.1	+25	50	14.3 *i*
U Lyncis		31.8	+59	57	14.6*d*	U Draconis		9.9	+67	7	13.0*d*
S Lyncis		35.9	+58	0	13.0*d*	χ Cygni		46.7	+32	40	<11.0
Y Monoc.		51.3	+11	22	<14	R Delphini	20	10.1	+ 8	47	<11.0
R Lyncis		53.0	+55	28	10.2*d*	U Cygni		16.5	+47	35	9.8*d*
R Gemin.	7	1.3	+22	52	12.2*d*	R Vulpeculae		59.9	+23	26	12.0*d*
V Can. Min.		1.5	+ 9	2	14.6*d*	X Cephei	21	3.6	+82	40	<12
R Can. Min.		3.2	+10	11	9.8*d*	T Cephei		8.2	+68	5	9.8 *i*
S Can. Min.		27.3	+ 8	32	8.6 *i*	S Cephei		36.5	+78	10	9.8*d*
RR Monoc.		12.4	+ 1	17	14.0*d*	SS Cygni		38.8	+43	8	11.8
U Gemin.		49.2	+22	16	14.0	S Lacertae	22	24.6	+39	48	9.0
RT Hydrae	8	24.7	− 5	59	9.2	Nova Lacertæ		31.8	+52	12	9.5*d*
S Hydrae		48.4	+ 3	27	11.0*d*	R Lacertae		38.8	+41	51	13.5*d*
T Hydrae	8	50.8	− 8	46	7.7 *i*	V Cassiop.	23	7.4	+59	8	<14
T Cancri		51.0	+20	14	10.0	RR Cassiop.		50.7	+53	8	13.2
R Leo. Min.	9	39.6	+34	58	9.8*d*	R Cassiop.		53.3	+50	50	6.6 *i*
R Leonis		42.2	+11	54	9.2 *i*	Y Cassiop.		58.2	+55	7	<13
R Urs. Maj.	10	37.6	+69	18	9.6*d*						

The letter *i* denotes that the light is increasing; the letter *d*, that the light is decreasing; the sign <, that the variable is fainter than the appended magnitude. The above magnitudes have been compiled by Mr. Leon Campbell of the Harvard College Observatory from observations made at the Amherst, Mt. Holyoke, Olcott, Jacobs, and Harvard, Observatories.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours, etc. For stars marked thus * alternate minima are given; ** every third minimum; † every tenth minimum.]

SY Androm.	d	h	*U Cephei	d	h	*Z Persei	d	h	*Z Persei	d	h	RY Persei	d	h
June	4	19	June	15	0	June	3	11	June	27	22	June	17	2
*U Cephei				20	0		9	14	RY Persei				23	22
June	5	1		24	23		15	17	June	3	8		30	19
	10	0		29	23		21	19		10	5			

Minima of Variable Stars of the Algol Type.—Continued.

**RZ Cassiop.

	d	h
June	4	13
	8	3
	11	17
	15	7
	18	21
	22	11
	26	1
	29	15

*ST Persei

	d	h
June	4	1
	9	8
	14	15
	19	23
	25	6
	30	13

RX Cephei

	d	h
June	3	14

*Algol

	d	h
June	5	11
	11	4
	16	22
	22	16
	28	9

**RT Persei

	d	h
June	3	0
	5	13
	8	2
	10	16
	13	5
	15	18
	18	7
	20	20
	23	9
	25	22
	28	12

λ Tauri

	d	h
June	2	8
	6	7
	10	6
	14	4
	18	3
	22	2
	26	1
	30	0

*RW Tauri

	d	h
June	1	6
	6	19
	12	8
	17	20
	23	9
	28	22

*RV Persei

	d	h
June	3	23
	7	21
	11	20
	15	19
	19	18
	23	16
	27	15

RW Persei

	d	h
June	11	19
	25	0

RS Cephei

	d	h
June	1	19
	14	5
	26	15

*RY Aurigae

	d	h
June	3	5
	8	16
	14	3
	19	14
	25	1
	30	12

*RZ Aurigæ

	d	h
June	1	12
	7	13
	13	14
	19	15
	25	16

51.1908 Gemin.

	d	h
June	3	9
	7	9
	11	10
	15	10
	19	10
	23	10
	27	10

*RW Gemin.

	d	h
June	5	20
	11	14
	17	7
	23	1
	28	18

*U Columbæ

	d	h
June	2	5
	7	19
	13	10
	19	0
	24	15
	30	5

*RW Monoc.

	d	h
June	4	4
	7	23
	11	19
	15	14
	19	10
	23	5
	27	1
	30	20

RX Gemin.

	d	h
June	2	23
	15	4
	27	9

**RU Monoc.

	d	h
June	1	2
	3	18
	6	11

**RU Monoc.

	d	h
Jnne	9	3
	11	20
	14	13
	17	5
	19	22
	22	14
	25	7
	27	23
	30	16

**R Canis Maj.

	d	h
June	3	22
	7	8
	10	19
	14	3
	17	13
	20	23
	24	8
	27	18

RY Gemin.

	d	h
June	8	12
	17	19
	27	2

*Y Camelop.

	d	h
June	4	3
	10	18
	17	8
	23	23
	30	14

RR Puppis

	d	h
June	7	0
	13	11
	19	21
	26	7

**V Puppis

	d	h
June	3	5
	7	13
	11	22
	16	7
	20	16
	25	0
	29	9

†X Carinæ

	d	h
June	2	8
	7	18
	13	4
	18	14
	24	0
	29	10

S Cancri

	d	h
June	4	1
	13	13
	23	0

S Velorum

	d	h
June	4	11
	10	9
	16	8
	22	6
	28	5

**Y Leonis

	d	h
June	2	23
	8	0
	13	2
	18	3
	23	4
	28	6

**RR Velorum

	d	h
June	5	20
	11	9
	16	23
	22	12
	28	2

*SS Carinae

	d	h
June	2	16
	9	7
	15	21
	22	12
	29	2

RW Urs. Maj.

	d	h
June	4	16
	12	0
	19	8
	26	16

**Z Draconis

	d	h
June	1	12
	5	14
	9	16
	13	17
	17	19
	21	21
	25	22
	30	0

*SS Centauri

	d	h
June	5	21
	10	20
	15	19
	20	18
	25	17
	30	16

*δ Libræ

	d	h
June	1	2
	5	18
	10	10
	15	1
	19	17
	24	9
	29	1

*U Coronæ

	d	h
June	4	4
	11	2
	17	23
	24	21

*SW Ophiuchi

	d	h
June	3	3
	8	0
	12	22
	17	19
	22	16
	27	14

*SX Ophiuchi

	d	h
June	3	15
	7	18
	11	21
	16	2
	20	4
	24	7
	28	10

R Aræ

	d	h
June	1	8
	5	18
	10	4
	14	14
	19	1
	23	11
	27	21

**U Ophiuchi

	d	h
May	1	3
	3	15
	6	4
	8	16
	11	4
	13	17
	16	5
	18	17
	21	6
	23	18
	26	7
	28	19

**SZ Herculis

	d	h
June	2	14
	5	1
	7	12
	9	23
	12	10
	14	21
	17	8
	19	19
	22	6
	24	17
	27	3
	29	14

Z Herculis

	d	h
June	3	7
	7	6
	11	6
	15	6
	19	6
	23	6
	27	6

SX Draconis

	d	h
June	2	22
	8	2
	13	7
	18	11
	23	15
	28	19

Minima of Variable Stars of the Algol Type.—Continued.

*RS Sagittarii

	d	h
June	2	4
	7	0
	11	20
	16	16
	21	12
	26	8

*V Serpentis

	d	h
June	4	9
	11	7
	18	5
	25	3

†RZ Draconis

	d	h
June	4	14
	10	2
	15	14
	21	2
	26	15

** RX Herculis

	d	h
June	2	20
	5	12
	8	4
	10	20
	13	12
	16	4
	18	20
	21	12
	24	4
	26	20
	29	12

*SX Sagittarii

	d	h
June	4	11
	8	14
	16	22
	21	1
	25	1
	29	9

*RR Draconis

	d	h
June	4	11
	10	3
	15	19
	21	11
	27	3

**U Scuti

	d	h
June	2	18
	5	15
	8	12
	11	9
	14	5
	17	2
	19	23
	22	20
	25	16
	28	13

*RX Draconis

	d	h
June	1	23
	5	18
	9	13
	13	8
	17	3
	20	21
	24	16
	28	11

*RV Lyræ

	d	h
June	4	10
	11	15
	18	20
	26	0

16.1908 Vulpec.

	d	h
June	3	14
	8	2
	12	13
	17	0
	21	12
	25	23
	30	11

*U Sagittae

	d	h
June	1	5
	7	23
	14	17
	21	12
	28	6

*Z Vulpec.

	d	h
June	3	4
	8	1
	12	23
	17	21
	22	19
	27	17

SY Cygni

	d	h
June	3	13
	9	13
	15	13
	21	13
	27	13

*WW Cygni

	d	h
June	2	22
	9	13
	16	4
	22	19
	29	11

SW Cygni

	d	h
June	2	18
	7	8
	11	22
	16	12
	21	1
	25	15
	30	5

VW Cygni

	d	h
June	9	3
	18	14
	27	0

*UW Cygni

	d	h
June	5	5
	12	3
	19	0
	25	22

W Delphini

	d	h
June	4	20
	9	16
	14	11
	19	7
	24	2
	28	21

RR Delphini

	d	h
June	2	15
	7	6
	11	20
	16	11
	21	1
	25	15
	30	6

RR Vulpec.

	d	h
June	3	8
	8	9
	13	10
	18	12
	23	13
	28	14

**VV Cygni

	d	h
June	1	6
	5	17
	10	3
	14	13
	19	0
	23	10
	27	20

**28.1910 Cygni

	d	h
June	3	14
	6	12
	9	10
	12	7
	15	5
	18	3
	21	1
	23	22
	26	20
	29	18

WZ Cygni

	d	h
June	30	10

*RT Lacertae

	d	h
June	3	5
	8	6
	13	8
	18	11
	23	12
	28	13

*TT Androm.

	d	h
June	1	9
	6	22
	12	11
	17	23
	23	9
	29	1

21.1909 Andr.

	d	h
June	4	22
	9	1
	13	4
	17	7
	21	10
	25	12
	29	15

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

SX Cassiop.

	d	h
June	3	16

SY Cassiop.

	d	h
June	1	19
	5	21
	9	23
	14	0
	18	2
	22	4
	26	6
	30	7

RW Cassiop.

	d	h
	(−5	19)
June	5	17
	20	12

SU Cassiop.

	d	h
	(−0	22)
June	1	13
	3	11
	5	10
	7	9
	9	8

SU Cassiop.

	d	h
June	11	6
	13	5
	15	4
	17	3
	19	2
	21	0
	22	23
	24	22
	26	21
	28	19

SU Cassiop.

	d	h
June	30	18

SV Persei

	d	h
June	11	9
	22	12

RX Aurigæ

	d	h
	(−4	0)
June	11	3
	22	18

SX Aurigae

	d	h
June	2	11
	4	0
	5	13
	7	2
	8	14
	10	3
	11	16
	13	5
	14	17
	16	6

Maxima of Variable Stars of Short Period not of the Algol Type.

Continued.

SX Aurigae			T Velorum			RZ Centauri			RV Ophiuchi			U Vulpec.		
	d	h		d	h		d	h		d	h		(−2	3)
June	17	19		(−1	10)		14	11		Minimum		June	7	19
	19	8	June	5	10	Jnne	15	10	June	1	11		15	18
	20	20		10	1		16	8		5	4		23	18
	22	9		14	17		17	7		8	20	SU Cygni		
	23	22		19	8		18	5		12	13		(−1	7)
	25	11		23	23		19	4		16	5	June	2	14
	26	23		28	15		20	2		19	22		6	10
	28	12	W Carinæ				21	1		23	14		10	7
	30	1		(−1	0)		21	23		27	7		14	3
SY Aurigae			June	3	11		22	22		30	23		17	23
June	3	18		7	20		23	21	X Sagittarii				21	20
	13	21		12	5		24	19		(−2	22)		25	16
	24	1		16	14		25	18	June	3	23		29	12
Y Aurigae				20	23		26	16		10	23			
	(−0	18)		25	8		27	15		18	0	η Aquilae		
June	2	21		29	17		28	13		25	0		(−2	6)
	6	18	S Muscæ				29	12	Y Ophiuchi			June	2	11
	10	14		(−3	11)		30	10		(−6	5)		9	15
	14	12	June	3	8	W Virginis			June	1	6		16	19
	18	8		13	0		(−8	5)		18	9		24	0
	22	4		22	16	June	14	4	W Sagittarii			S Sagittae		
	26	1	T Crucis			V Centauri				(−3	0)		(−3	10)
	29	22		(−2	2)		(−1	11)	June	5	1	June	6	4
RZ Gemin.			June	7	13	June	1	22		12	15		14	13
	(−1	7)		14	7		7	10		20	5		22	22
June	1	20		21	0		12	22		27	20	X Vulpec.		
	7	9		27	18		18	10	Y Sagittarii				(−2	1)
	12	21					23	22		(−2	2)	June	1	4
	18	9	R Crucis				29	10	June	5	4		7	12
	23	22		(−1	10)	R Triang. Austr.				10	22		13	20
	29	10	June	4	4		(−1	0)		16	17		20	3
RS Orionis				10	0	June	2	14		22	11		26	11
	(−2	0)		15	19		5	23		28	6			
June	7	15		21	15		9	9	U Sagittarii			V Vulpec.		
	15	5		27	11		12	18		(−2	23)	Minimum		
	22	18	S Crucis				16	3	June	4	1	June	19	21
	30	8		(−1	12)		19	13		10	19			
T Monoc.			June	3	13		22	22		17	14	X Cygni		
	(−9	23)		8	6		26	7		24	6		(−6	19)
June	7	23		12	22		29	17	β Lyræ			June	14	22
W Gemin.				17	15	S Triang. Austr.				(−3	7)			
	(−2	2)		22	7	June	2	8		(−3	2)	T Vulpec.		
June	7	10		27	0		8	16	June	2	14		(−1	10)
	15	8	RZ Centauri				15	0		9	14	June	2	18
	23	6	June	1	8		21	7		16	12		7	5
ζ Gemin.				2	7		27	15		23	4		11	15
	(−5	0)		3	5	S Normæ				29	10		16	2
June	2	3		4	4		(−4	10)	κ Pavonis				20	12
	12	6		5	2	June	5	18		(−4	7)		24	22
	22	10		6	1		15	12	June	6	8		29	8
RU Camelop.				6	23		25	7		15	11	TX Cygni		
	(−9	12)		7	22	RV Scorpii				24	13	June	4	22
June	13	4		8	20		(−1	10)	U Aquilæ				19	16
V Carinæ				9	19	June	2	19		(−2	4)			
	(−2	4)		10	17		8	20	June	8	0	VY Cygni		
June	3	3		11	16		14	22		15	0		(−2	14)
	9	20		12	14					22	1	June	4	10
	16	13		13	13					29	1		12	7
	23	5											20	3
	29	22											28	0

Maxima of Variable Stars of Short Period not of the Algol Type.
Continued.

VZ Cygni		Y Lacertae		RR Lacertae		X Lacertae		RS Cassiop.	
d	h	d	h	d	h	d	h	d	h
(−1	1)	June 19	12	June 3	0	June 4	10	(−1	19)
June 4	4	23	20	9	11	9	21	June 2	2
9	0	28	4	15	21	15	7	8	9
13	21	δ Cephei		22	7	20	18	14	16
18	18	June 5	8	28	17	26	4	21	23
23	15	10	17	V Lacertae		SW Cassiop.		27	6
28	11	16	2	(−1	10)	June 1	5	RY Cassiop.	
Y Lacertae		21	10	June 5	0	6	16	(−7	10)
(−1	10)	26	19	9	23	12	2	June 12	5
June 2	5	Z Lacertae		14	23	17	12	24	9
6	13	June 5	12	19	22	22	23		
10	21	16	10	24	22	28	9		
15	4	27	7	29	22				

Errata.—The times of the Maxima given for U Sagittarii in the April number for May have been found to be in error by about seven hours. The times of the maxima are as follows: May 7 1
13 19
20 13
27 7

Also β Lyrae should be May 2 12 instead of 1 12 as given.

COMMUNICATIONS QUESTIONS AND ANSWERS.

[This department is designed especially for the use of amateurs. Beginners are invited to send in their puzzling questions. The editors will try to see that answers are given to reasonable questions but will not hold themselves responsible for the correctness of the views expressed in the communications which may find place here. All communications should be brief.]

How the Planets are warmed by the Sun.—The suggestions made herein are not offered in a dogmatic spirit. They are not claimed to be "science". No term in the language is more abused. It is derived from the splendid Roman word *scio*, which means, I know. With a few exceptions astronomy is not yet an exact science. Many of the statements made by its teachers are the veriest guess-work. This article may not be more.

One of the favorite themes of astronomers is the amount of heat which the Sun throws off into space. Elaborate calculations are made to show the number of cubic miles of coal that would have to be consumed each year, to supply this heat. The source of the heat, continued in an inexhaustible stream for millions of years, has hardly been conjectured. The only theory seems to be that the Sun contracts its size, to a certain extent each year, and this forces out the heat.

Now the rays of the Sun contain but two elements which need enter into this discussion, light and heat. These two elements bear little relative proportion to each other. The light of the Sun may possess exceeding brilliancy with the temperature far below the freezing point. Snow-blindness, in the arctic regions, is a familiar example of this fact.

To the writer it seems that the Sun is a huge dynamo, which gathers and transmits some form of electrical energy. The ether is the conductor of tnis energy, without being warmed thereby. The atmosphere of the planets receives this energy and, in some manner not yet understood, transforms it into the warmth that sustains all life.

The universe is stored with electrical energy. It seems to be one of the principal agencies by which The Creator carries on his work. The Sun revolves on its axis at such a rate that a point on its surface, at its equator, moves more than a mile each second. It is more than probable that this speed enables it to draw electricity or some form of energy akin thereto, from the illimitable spaces of the universe.

And the ether, that mysterious element that fills all space, is a conductor of this energy, of which we speak, far superior to any metal wire that man has made.

The ether is inconceivably cold. There is no method of measuring the intensity of this cold, but conservative estimates place it at from three to five hundred degrees, Fahrenheit, below zero. And like other conductors of electricity, the ether receives and transmits the energy of the Sun without itself receiving any warmth therefrom.

And, when this energy reaches the Earth's atmosphere, it undergoes a change. In passing through more than ninety millions of miles of deadly cold, no heat escapes. The action is, apparently, somewhat analagous to that of the wire, which, itself unwarmed, conveys the electric current from the dynamo to the arc-light, where it may create a temperature thousands of degrees in intensity.

This transformation of solar energy into warmth appears to be governed by general laws. On high mountains it isinsufficient to melt the snow, which remains there forever. This shows that the atmosphere must possess a certain density to transform these rays into heat.

It will be observed, too, that the slanting rays of the Sun, in winter, and in the morning and evening, do not produce the effect of the vertical rays, and from this the rule may be deduced that the smaller the angle of incidence and reflection, the greater the transformation of heat, and *vice versa*.

It has always been the opinion of astronomers that the nearer a planet is to the Sun, the greater the amount of heat it receives from its rays and the farther away, the less. If this were true, the Earth should receive more heat from the Sun in December, when it is about 91,000,000 miles from the Sun than it does in June when it is nearly 95,000,000 miles away. But such is certainly not the case in the Northern hemisphere, and there is no evidence that the Southern hemisphere is the warmer of the two. If distance made any difference, it should have an increased average temperature of nearly four per cent.

Again, the planet Mars has an average distance from the Sun of about 135,000,000 miles. while the average distance of the Earth is about 93,000,000 miles. The average heat of Mars should therefore be far less than that of the Earth. But careful observations, for many years, show that the Martian polar snows entirely melt and disappear in the summer of that planet and that the waters flow forth to make those belts of vegetation which have been given the name of "Canals." Were an observer on Venus, for instance. to turn his telescope on the Earth, he would never see the time when there was not a large cap of snow around the north and south poles. This leads me to believe

that the atmosphere of Mars may be so constituted as to develop more heat from the ray energy of the Sun than is developed by our atmosphere.

As we ascend the mountains, the density of the atmosphere decreases, and the heat of the Sun decreases in the same proportion. It follows as a rational conclusion, that where there is no atmosphere there can be no warmth from the Sun's rays.

No trace of an atmosphere has been found on the Moon. It therefore receives light from the Sun, but no heat, and its temperature is probably that of the measureless cold herein before referred to.

All the planets appear to have atmospheres, except, perhaps, Mercury, and so, all except that one may receive heat from the Sun. If the heat were transmitted from the Sun by ordinary radiation, then Mars would receive only about half as much heat as the Earth, Jupiter about one fifth, Saturn less than one ninth, Uranus about one twentieth and Neptune about one thirtieth. If this were true, then life as we know it could exist only on Venus, the Earth and Mars; Jupiter, Saturn, Uranus and Neptune, the largest and most splendid of the planets, would be forever utterly useless.

The mass of the Sun is about seven hundred and fifty times that of all the planets and satellites that revolve around it. Its appointed task, so far as the human mind can discern, is to give light and warmth to its dependents. The wire that leads out from the dynamo does not furnish light and heat alone to the lamps which it first reaches, but its influence is felt alike by all on the circuit. And the current not used in the lamps is not wasted or thrown away.

The Creator follows a general plan with infinite variations. While grains of sand, blades of grass and leaves of the forest resemble each other in a general way, no two are ever exactly alike. The same rule applies to the world's that revolve around the Sun. Observations show that the outer planets have atmospheres of great extent and density.

Neptune is about forty five times as far from the Sun as Venus is, but the light reflected from Neptune bears no proportion to the distances. To an inhabitant of Neptune, our Sun, if observed under conditions such as we know, would be only a magnificent star, not much larger than Jupiter appears to us. But the same power that makes infinite variations in the leaves, the grass and the sand, can and probably has so created the atmosphere of that planet, as to enable it to transform the solar energy into warmth, at least equal to that found in the Earth's tropical regions. To believe otherwise would be to hold that The Great Architect had no other plans or materials, save only such as he used in this little world of ours.

H. N. Atkinson.

Houston, Texas, February 24, 1911.

Professor R. W. McFarland LL. D.—We have received from Mr. I. N. Snyder a further tribute to the life and work of Dr. McFarland, a brief account of whose life, and mention of whose death were given in the preceding number. Mr. Snyder had personal and intimate acquaintance with Dr. McFarland having been a student under him during his years of teaching in Miami University. The writer speaks of him as follows: "He was a man of dignified appearance, slightly above the average in height, and carried himself very erect always walking with a quick, firm, military step—in fact a man to be noted in an audience for his robustness of figure and stately bearing. It

was as a student in his class that my best acquaintance with him was formed. He had a pleasing address, and was a firm friend, and often aided his students outside of the class room when he knew they were in earnest and in need of assistance. Professor McFarland had a wonderful mathematical memory and seldom used the text book in the class room. I had occasion to accompany him on several surveying trips; he never used a note book on these occasions, but after getting the angles and measurements with compass and chain he would stop, run over the figures in his mind until they were fixed and then at night he would make the plat, feeling confident that it was correct. His maxim was that one should trust the memory or it would deceive him. He possessed a keen appreciation of humor, which at times manifested itself in the class room. His characteristic advice was to use the shortest method in solving a problem.

"Dr. McFarland's life was a busy one. Idleness was not in his vocabulary. He always read his mail as he walked from the post office, pausing only to greet a friend or to talk briefly with a neighbor. As an instructor in mathematics and astronomy he had few equals. His literary and technical writings will live long after him. He was successful on the lecture platform, and humanity is richer because of his eighty five years of usefulness."

GENERAL NOTES.

Owing to an extraordinary sale, No's 156, June-July 1908; 161, January 1909; 169, November 1909; 170, December 1909, are out of our files. Requests for these numbers have not been numerous enough to warrant the reprinting of any of the issues, but still a number of our subscribers need them to complete their files of POPULAR ASTRONOMY. If any of our readers, therefore, have made all the use they care to of these numbers, and care to dispose of them, we should be very glad to buy them back at the rate of 30 cents a copy.

Miss Harriet W. Bigelow has been promoted to the professorship of astronomy at Smith College.

Dr. Osten Bergstrand, for some time observer at the Upsala Observatory, Sweden, has been appointed professor of astronomy in the Upsala University and director of the observatory. *Science*, March 31.

Dr. Lewis Boss, director of the Dudley Observatory and of the department of meridian astronomy of the Carnegie Institution, has been elected a corresponding member of the Academy of Sciences of St. Petersburg. *Science*, March 31.

A Portrait of David Rittenhouse, painted in 1772 by Rembrandt Peale, has been given to the University of Pennsylvania by Mrs. Wm. Lawber. David Rittenhouse was Professor of astronomy and vice-provost of the University from 1779-1782, and from 1782 until the time of his death, a trustee. *Science*, March 31.

Dr. C. G. Abbot, director of the Astrophysical Observatory of the Smithsonian Institution, will this summer conduct an expedition to southern Mexico to make measurements of the Sun's radiation, which will be compared with simultaneous observations on Mount Wilson. The congress has made a special appropriation of $5,000 for this work. *Science*, April 7.

Genesis of the Law of Gravitation.—*Popular Science Monthly* for April 1911 contains an interesting historical account of the Genesis of the Law of Gravity by Professor John C. Shedd of Olivet College, Olivet, Mich.

Correction of Orbits.—In *Bulletin Astronomique* for March 1911 Mr. C. Popovici gives formulæ for correcting the elements for an orbit by means of a single observation.

Periodicity of Sun-spots.—In the Proceedings of the Roval Society No. A 575 Dr. Arthur Schuster gives a short note on the Periodicity of Sun-spots, in which he calls attention to the verification, by the Greenwich Sun-spot records from 1899 to 1909, of a period of 4.79 years superposed upon the well-known eleven year period. He says that a period of 4.38 years and one of 8.36 years, suggested by him in 1906, receive no support from the recent observations.

Precession Formulæ.—In *Bulletin Astronomique* for March 1911 Mr. H. Andoyer develops a collection of precession formulæ, using the constants of Newcomb, which were adopted at the International conference at Paris in 1906. Using 1900.0 as the initial epoch, the general annual precession at any other epoch may be obtained by the formula

$$l = 50''.25641 + 0''.0002223\ t$$

and the precession in right ascension and declination by

$$m = 46''.08505 + 0''.0002795\ t$$
$$n = 20''.04686 - 0''.0000853\ t.$$

Appropriations of the American Academy of Arts and Sciences.—At the last meeting of the Rumford Committee of the American Academy of Arts and Sciences the following appropriations were made: To Professor D. F. Comstock of the Massachusetts Institute of Technology, $100 in aid of his research on the possible effect of the motion of the source on the velocity of light. To Professor G. N. Lewis, of the same institution, $150 in aid of his research on the free energy changes in chemical reactions. To Professor R. W. Wood, of John Hopkins University, $150 in furtherance of his researches on the optical properties of vapors.

The Absorption of the Light of the Stars by Meteorites.—It is possible to compute, if we grant that the Earth receives annually the amount of cosmical dust indicated by Arrhenius, the amount of this material in space. Assuming that this material extends with the same density throughout all space, one can compute the amount of absorption, caused by that medium, of the light of the stars. It is found that the apparent diminution of the number of stars with the distance and the faint light that comes from all the stars together can be reconciled on the hypothesis of an almost uniform distribution of stars in space and an equal absorption. It is possible then that the aspect of the starry heavens is produced not by a particular distribution of the stars in a mass that does not extend much farther than the most distant visible stars, but by the absorption of the meteorites that people interstellar space.

P. Salet, in L'Astronomie. March, 1911.

The Astronomical Society of Spain.—A new astronomical society is being formed in Barcelonia by M. Jose Comas Sola, Director of the Observatory, Fabra. This new association, which takes the title of "The Astronomical Society of Spain," will publish the principal astronomical and seismological works of the whole world. It counts among its supporters already many men both in Spain and in America. The Astronomical Society of France in sending greetings to its young sister in Spain is very kind to verify the important development taken by astronomy in Spain and particularly in Barcelonia. We have, indeed, announced before, the founding by M. Salvador Raurich of the "Astronomical Society of Barcelonia." The science of the sky has developed very rapidly and we always note with pleasure its progress.

L'Astronomie, March, 1911.

Astronomical Investigations of the Carnegie Institution.

Science for March 24 contains an interesting report of the various scientific investigations being carried on under the auspices of the Carnegie Institution. It is interesting to note the exceptional progress which is being made in the two departments of astronomical research. The observatories for the determination of fundamental star positions in the southern hemisphere have been carried on very rapidly and were completed early in March. The instruments have been shipped to Albany and the members of the expedition are returning at various times. Arrangements for the computation of the results of these observations are being made at the Dudley Observatory. Already a preliminary catalogue containing the positions of 6188 stars for the epoch 1900 has been issued and the director has published also, through the Dudley Observatory, a "list of 1059 standard stars" to aid in the work.

Concerning the work at the Mt. Wilson Solar Observatory, the writer says, The rapid growth in equipment and facilities and the equally rapid progress in the production of capital results from the researches at this observatory are at once sources of surprise and gratification to the astronomical world. Work during the past year has gone on with little diminution of vigor although the illness of the director has forced him to relinquish his activities for a considerable portion of the time. He has recently gone abroad for a season and the departmental report for the past year has been prepared by Mr. Walter S. Adams, now acting director of the observatory.

"The work of this establishment is now so extensive and so varied that it is somewhat difficult to summarize even in its salient aspects. In addition to the observatory proper with its four principal telescopes and much auxiliary equipment on Mt. Wilson, there are the physical laboratory and the instrument shops at Pasadena, along with special divisions devoted to the work of computations and construction respectively. To become conversant, therefore, with the complexity of activities of this department, one must read the somewhat lengthy but relatively condensed annual report of the director.

"By way of equipment several large pieces of apparatus for the new tower telescope, for the 60-inch telescope, and for the 100-inch grinding machine have been made at the shops. The towers for the new 150-foot tower telescope, begun a year ago, are now finished along with the well, 75 feet deep in the rock below, which forms a part of the telescope tube of this novel instrument now essentially complete except for its spectroscopic attachments still under construction at the shops. Some preliminary trials made recently with this instrument indicate that it will fulfill the sanguine expectations entertained in respect to its capacity.

"At the time of the annual meeting of the board of trustees a year ago 'The Monastary', a wooden building on Mt. Wilson supplying quarters for the resident members of the observatory staff, was completely destroyed, along with a considerable number of books and other valuable property, by fire. This building has been replaced during the year in somewhat enlarged form by a reinforced concrete structure.

"Progress has been made during the year in the details of designs for the proposed 100-inch or "Hooker" telescope, for which Mr. J. D. Hooker, of Los Angeles, made a substantial gift to the observatory some years ago. This work has been in charge of Professor Ritchey, whose construction of the 60-inch reflector has proved so signally successful. After repeated trials and failures to make a satisfactory disk the contracting firm at St. Gobain, France, have quite recently renewed the hope that a disk they now have annealing may meet the exacting requirements set by astronomers."

The meeting of the International Union for coöperation in Solar Research, an account of which appeared in the October number of POPULAR ASTRONOMY, was held at this observatory, and the visiting astronomers showed a keen appreciation of the equipment of the observatory and the perfection of the telescopes.

A Flock of Stars.—Mention has been previously made in these pages of groups of stars the individual members of which appear to be moving in parallel lines in space and with equal velocity. The group of thirty-nine stars in Taurus detected by Professor Boss was one, whilst Sirius and five stars in Ursa Major made up another case. Recently a similar group has been detected by Professor Stoorbant, who arrives at his conclusion (*Bulletin Astronomique*, 1910 November) in a different and perhaps more direct way than that adopted by other investigators. Professor Boss, for example, having noticed the existance of proper motions pertaining to certain stars separated by some degrees, which converged to a point, showed that the direction and amounts of these proper motions would be accurately accounted for if the stars were at certain relative distances and were moving in a flock as before described. Professor

Stoorbant, on the other hand, chooses seven stars for certain reasons (because their proper motions were small) about which he has fairly complete information. These stars are α Cassiopeia, β Persei, α Persei, α Scorpii, γ Cygni, ε Pegasi, and α Pegasi, and of all of these the parallax, the motion in the line of sight, and the proper motion have been determined. From these data Professor Stoorbant computes the actual position of each star in space, and its absolute velocity in space in kilometers per second. This last for the seven stars ranges from 11.3 to 22.1 km., which, as Professor Stoorbant points out, is not very different from the velocity of our Sun, assumed to be 19.4 km. per second, and, what is perhaps more remarkable, the directions of the movement of the eight bodies are parallel within a range of about six degrees.

The Observatory, March, 1911.

Heinrich Christian Schumacher, the first Editor of the "Astronomische Nachrichten".—The *Astronomische Nachrichten* was begun in September 1821 and has had continuous existence from that time to this. The scheme was to publish a number whenever a sufficient amount of original matter should be accumulated. As a matter of fact, No. 4490 has recently appeared so that, for the average of its ninety years, about fifty numbers have been issued each year, or nearly one each week. We take from an article by W. T. Lynn in the *Observatory* for March 1911 the following account of the life of its first editor. "Heinrich Christian Schumacher was born at Bramstedt, in Holstein, on the 3rd of September, 1780. His father died when he was only ten years of age, and his mother, to whom a pension was allowed by the Crown Prince of Denmark, settled at Altona. There young Schumacher attended the Gymnasium, then presided over by Jacob Struve, father of the famous F. G. W. Struve. He early developed a taste for mathematics and mechanics, but his health as a boy was not strong. He went to Kiel in 1799 with the intention of taking up the law as his profession, and it was there that he became both an excellent classical scholar and an adept in several modern languages. In 1802 the Russian Emperor Alexander I. founded the University of Dorpat. Here Schumacher removed and devoted himself chiefly to mathematical and scientific studies under the guidance of J. W. Pfaff, Professor of Astronomy and Mathematics at Dorpat. He qualified as jurist at Göttingen in 1806, but did not pursue the law as a profession, his true bent being mathematics and science. He had some idea of going to Paris and working under Lalande, but the death of the latter in 1807 prevented this, and he then returned to Altona, afterwards going for a time again to Göttingen, where he studied under Gauss and made the acquaintance of Olbers. In 1810 he was appointed Extraordinary Professor of Astronomy at Copenhagan, but instead of going there immediately took charge of the small observatory at Mannheim. When Bugge died in 1815 he removed to Copenhagen. Five years later he returned once more to Altona, where there was entrusted to him the superintendence of the geodetic operations in Holstein, to aid in which the king (Frederick VI.) established in 1823 a small observatory at Altona. This occupied him for several years, and he took part in the connection of the Danish with the English triangulation by the determination of the difference of longitude between Greenwich and Altona.

"Schumacher continued to edit the *Astronomische Nachrichten* until his death on the 28th of December, 1850, though his health failed considerably during the last year, early in which he thought he should not see it out. He

had received the Gold Medal of the Astronomical Society in 1829, the address being given by Sir John Herschel, who remarked on the way in which the *Nachrichten* formed 'a point of concourse, a complete bond of union amongst astronomers' in different countries."

In the *Observatory* for April 1911, Mr. J. L. E. Dreyer calls attention to the following quotations from letters written by Schumacher to Gauss. On March 27, 1821, "Our Finance Minister has almost called upon me to publish an astronomical journal in Altona, of which there should appear every week about one sheet, and which should serve to keep up the most lively communication among astronomers." And again on April 10th, 1821, "Everybody will think that the idea is my own, but it belongs really to our Finance-Minister, and was not suggested to him."

The name of Mösting, the Danish Finance-Minister referred to in the quotation (who died in 1843), is now very familiar to astronomers through the important lunar crater named after him.

Looking Skyward.—A new book by Isaac Newton Snyder bearing the title "Looking Skyward" has recently come to our desk. The author indicates in the preface that he was led to write the book by the suggestion of Professor Campbell, that a number of people should write descriptions of the recent appearance of Halley's comet in such form that they might be preserved until the next return of the comet seventy-five years hence. The book contains 148 pages, and is divided into seventeen chapters. Besides a chapter on Halley's comet there is a brief chapter on comets in general, and other chapters on the Sun, the Moon, Venus, Origin of the Solar System, Asteroids and some others.

The author touches upon a number of the well-known theories of astronomy, and although his treatment is by no means exhaustive gives much interesting information concerning the current beliefs in Astronomy. The book contains twenty-five illustrations of various objects of the sky, such as the nebula in Orion and in Andromeda, and of Venus, Jupiter and Saturn. The book would, no doubt, be found interesting to one who is approaching the subject of astronomy for the first time.

The Observers Hand book for 1911, published by the Royal Astronmical Society of Canada, which has recently come to our desk, contains in a condensed form much valuable information for one who does not have access to the *American Ephemeris* or some similar book. The current issue is late but the one for 1912 is in preparation and will be published before January 1. It contains the times of rising and setting of the Sun for each day in the year; also the planetary configurations for each month, together with other interesting events such as the times of minima of Algol; Also a description of the eclipses of the Sun and of the Moon for the year; A list of the brighter stars that are occulted by the Moon during the year; also a brief account of the comets observed in 1910, and those due in 1911; a table of Radiant points of meteoric showers; a short list of variable stars; a table of the elements of the solar system, and the constellations and their positions for each month of the year.